Introduction to the cryogenics for superconducting systems

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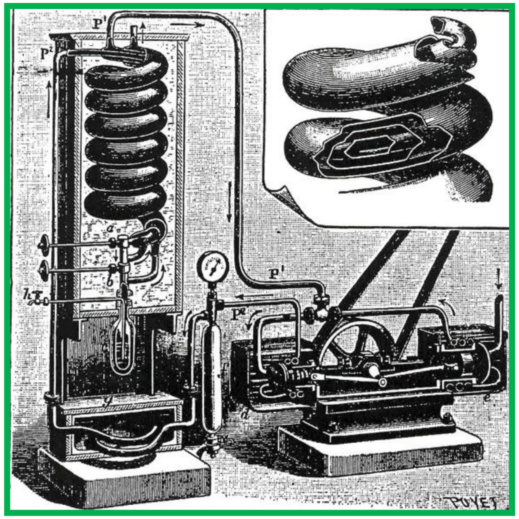

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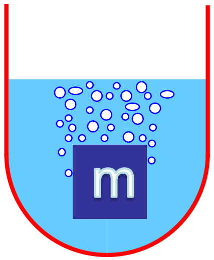
Summary

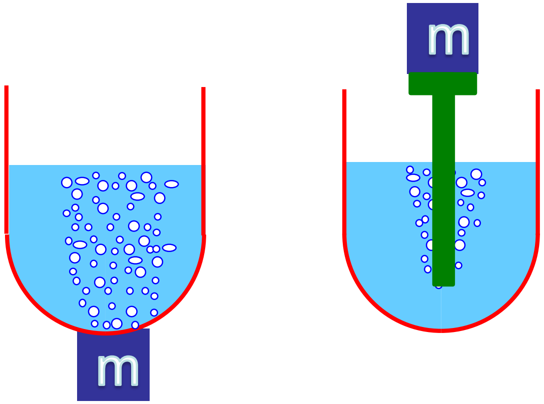
- Quick history of gas refrigeration and basic concepts of helium machines. Various cycles :
    - Vapor compression cycle
    - Linde’s cycle
    - Brayton’s cycle
    - Claude’ cycle
- Current general configuration
- Main components of helium refrigerators
    - Compressor
    - Heat exchangers
    - Turbo-expanders
- Integration in superconducting magnet cooling. Example.
- Efficiency

Basic reminders

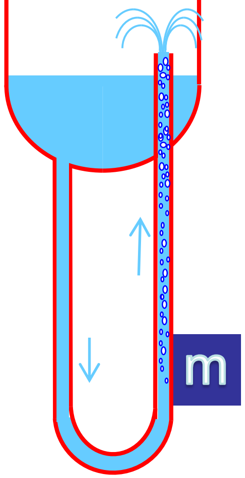
Still today, superconducting state requires low temperature and consequently use of cryogenic fluids



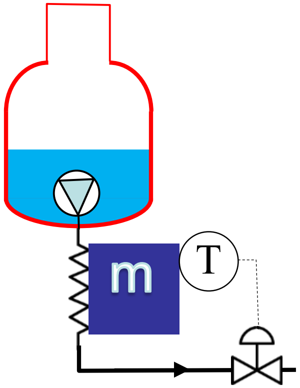
Direct cooling (bath)



Indirect cooling



Natural flow (thermosisphon)



Forced flow

- LHe for many applications with Low Temperature Sc (majority)
- LH_2 and LN_2 when High Temperature Superconductors (still rare)

Basic reminders

2 ways to obtain these cryogenic fluids

- **buy cryogenic fluid** and use it for cooling (latent heat of vaporization or by heat capacity)

    Initial low investment

    Supplier dependence

    High cost during exploitation


courtesy Air Products

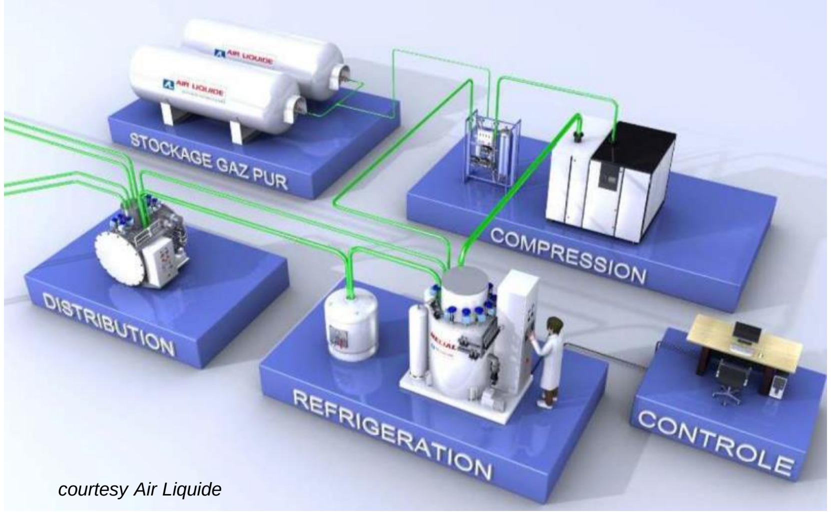
💣 : *helium gas is derived from extraction of fossil fuels and now considered as a strategic matter*

Fluid	**He^4**	**H_2**	**Ne**	**N_2**	**Ar**	**O_2**
Boiling temperature at Patm in K	**4,2**	**20,4**	**27,1**	**77,3**	**87,3**	**90,2**
Latent heat of vaporization in J.g^{-1}	**21**	**452**	**86**	**199**	**157**	**213**
Vaporization rate(*****) in W.h.l^{-1}	**0,7**	**9,0**	**29,0**	**45**	**61**	**68**
Approximative cost for one liter in **€/liter** (for large delivered quantity)	*40 €/liter*			*0,12*	*> 15*	

(*) : number of watts needed to vaporize one liter of liquid in 1 hour

Basic reminders

- Produce the cryogenic fluid locally and **install an autonomous refrigeration equipment** (refrigerator, liquefier) able to produce and/or to liquefy a fluid at low temperature
  - High cost initial investment
  - Low independence from supplier
  - Flexibility and adaptability
  - Sustainable for exploitation

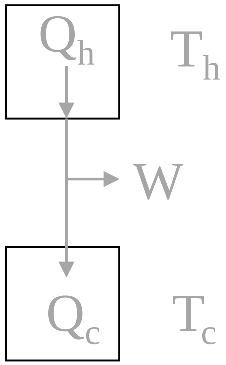


courtesy Air Liquide

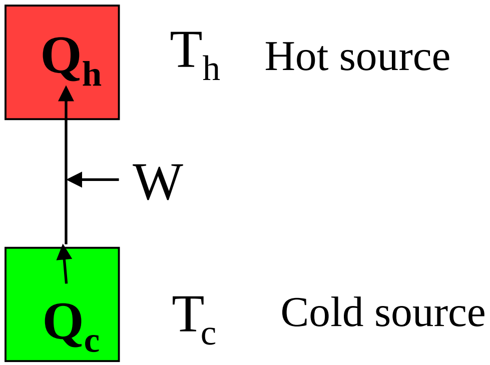
Commonly, testing or operating large superconducting magnet needs a **CRYOPLANT** where the core is a gas-cycle refrigerator (or liquefier).

Thermodynamic reminders for refrigeration

To cool down or/and liquefy a gas, an adapted thermodynamical cycle is needed, exhausting heat at hot source with an absorption of work, for extracting caloric energy at cold source.



Thermal engine



Refrigerator

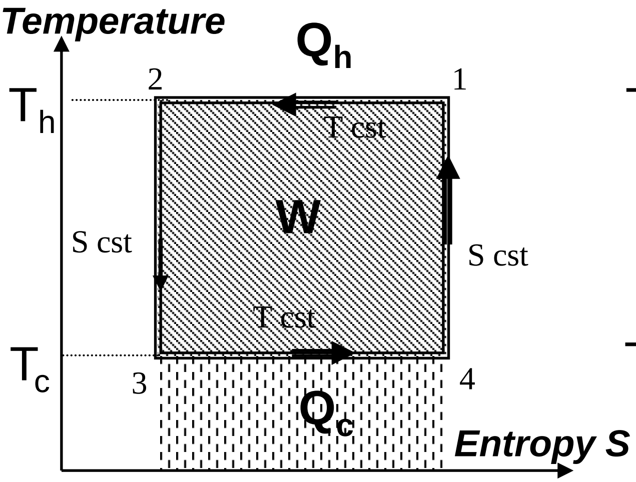
What thermodynamic says :

*Heat cannot flow spontaneously (without compensation) from cold source towards hot source => **work W is needed***

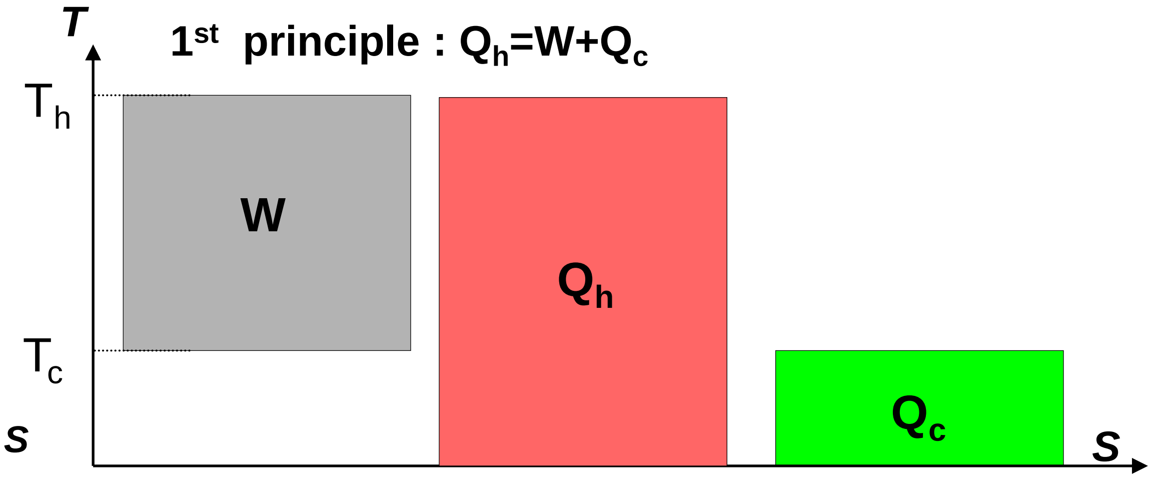
It is impossible that a system can absorb refrigeration from the external environment with a monothermal cycle => T_c *and* T_f *as **2 sources at minimum***

Ideal Refrigeration

Ideal Carnot cycle (reverse cycle) (2 isothermals + 2 isentropics)



1^{st} principle : $Q_h = W + Q_c$



For a gas closed cycle , 4 steps :

- 1- 2 : Isothermal compression (exhaust of **Qh** from the hot source)
- 2-3 : Adiabatic cooling down
- 3-4 : Isothermal transf (absorption of **Qc** by the cold source)
- 4-1 : Adiabatic warming up

$$COP(Carnot) = \frac{Q_C}{W} = \frac{T_c}{T_h - T_c}$$

Coefficient of performance

$$Specific\ power\ (W/W) = \frac{1}{COP} = \frac{W}{Q_C}$$

Needed power to absorb 1 W at T_c

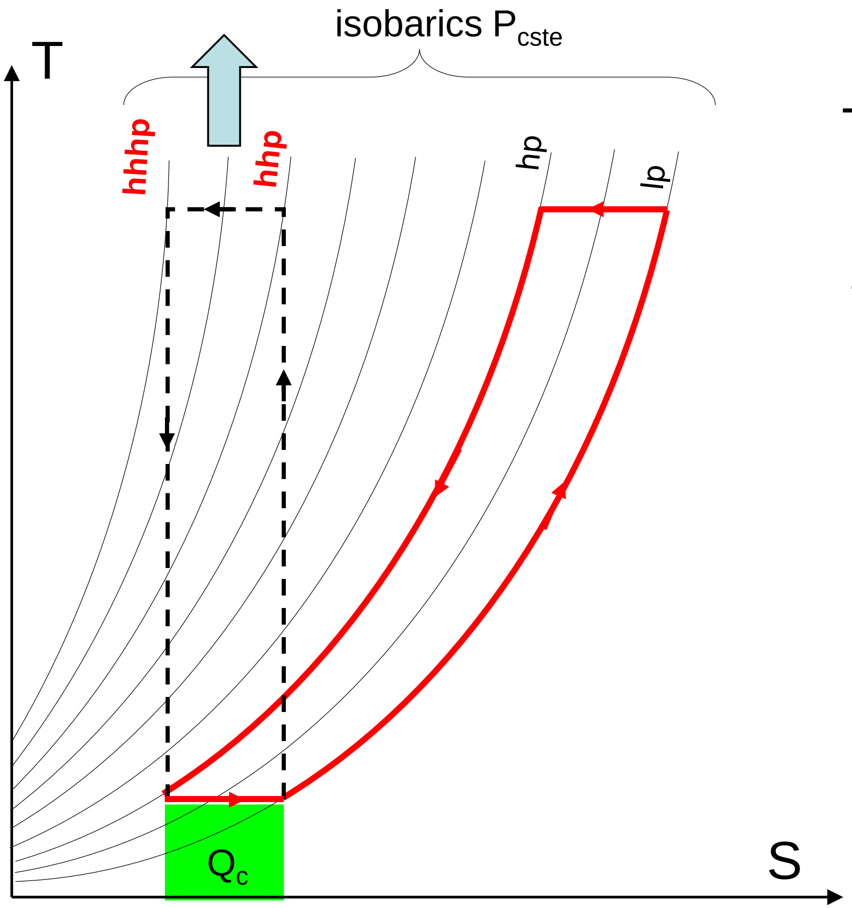
as « reference performances »

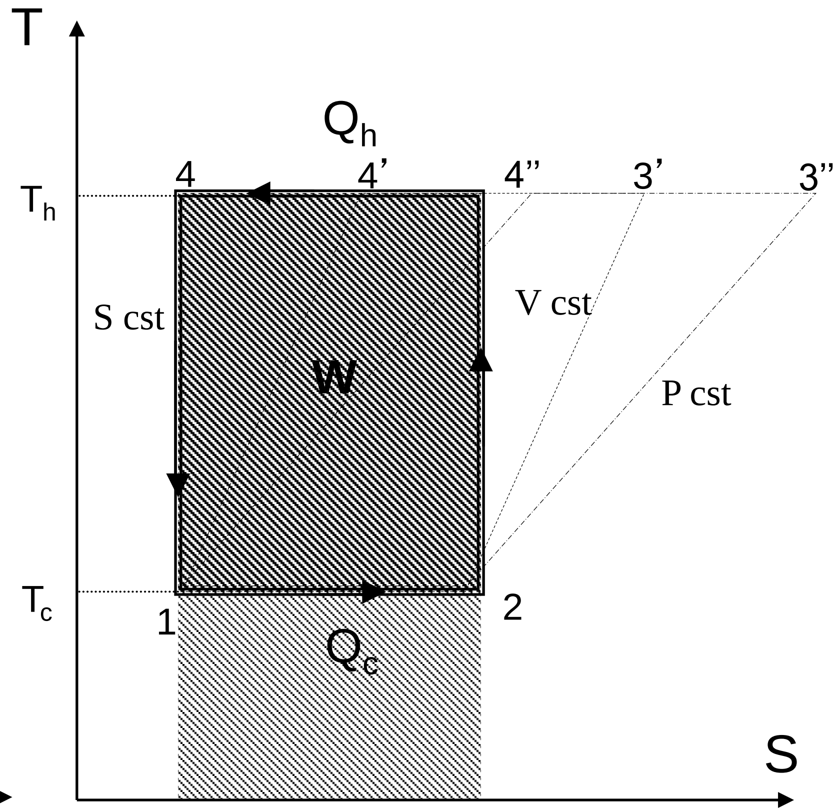
T_h=293 K	T_c 4,2 K	T_c= 20 K	T_c=77 K
$1/COP\ (W_{\text{at }293\text{ K}}/W_{\text{at }T_f})$	**70**	**14**	**2,9**

Equivalent cycles compared to Carnot ideal cycle

Very high P
+ ΔS= 0 along large DT

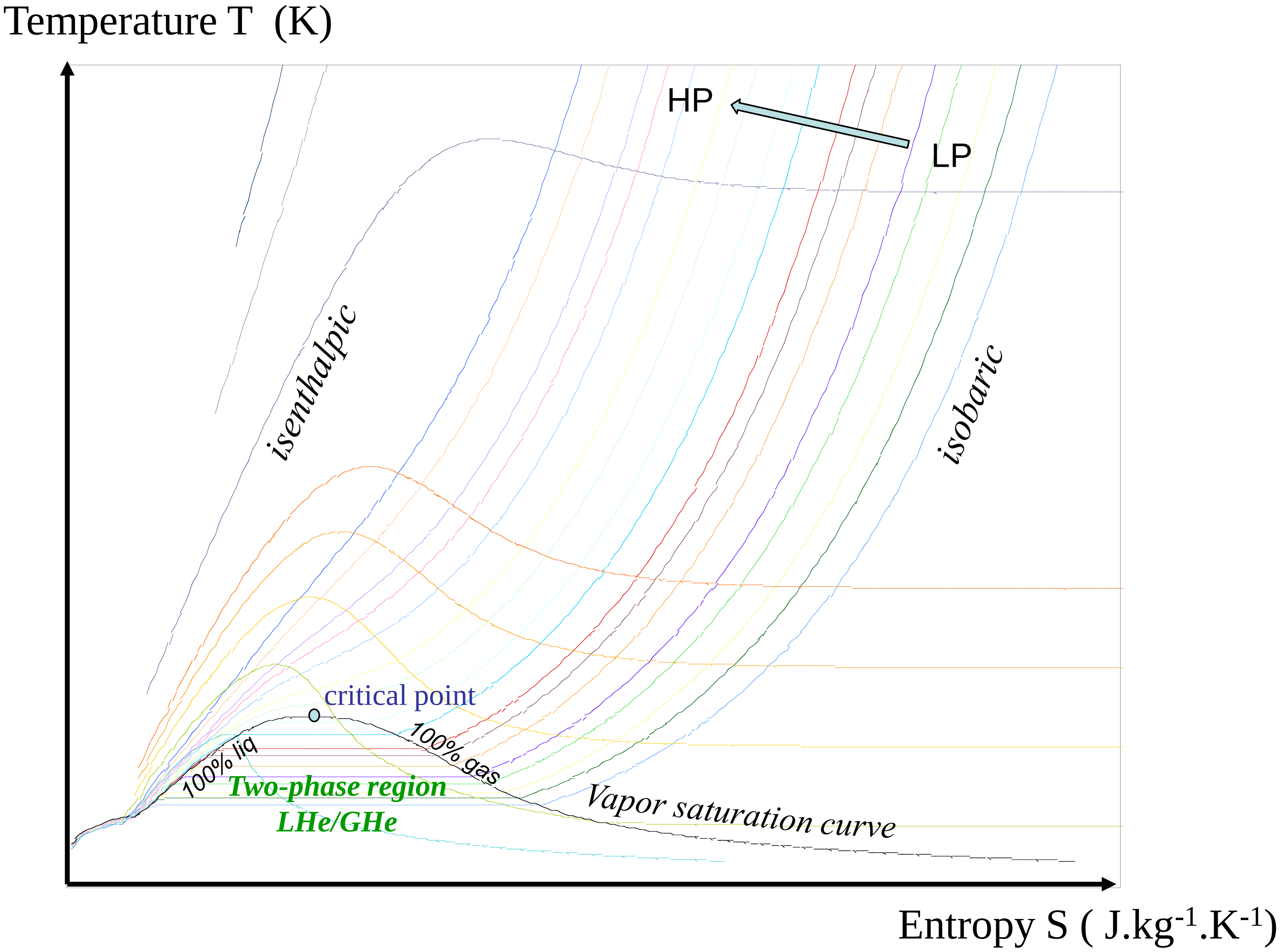
Replace isentropics by **isobarics** or **isochorics**. Same efficiency than Carnot
(for a perfect gas where isobaric curves are parallel…)





1-2-3-4 : **Carnot** (isothermal-isentropic)
1-2-3'-4' : **Stirling** (isothermal-isochoric)
1-2-3''-4'': **Ericsson** (isothermal-isobaric)

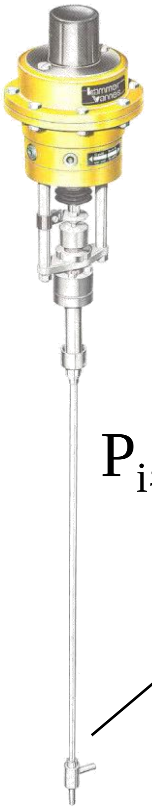
T-S diagram (Helium at low temperature)



What kind of gas expansion can be realized for reaching low temperature ?

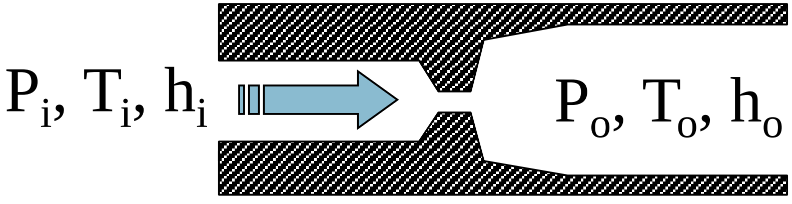
« Joule-Thomson » expansion

Adiabatic and without external work (only internal work)
=> isenthalpic but irreversible



Cryogenic valve

$\Delta Q = \Delta W = 0$



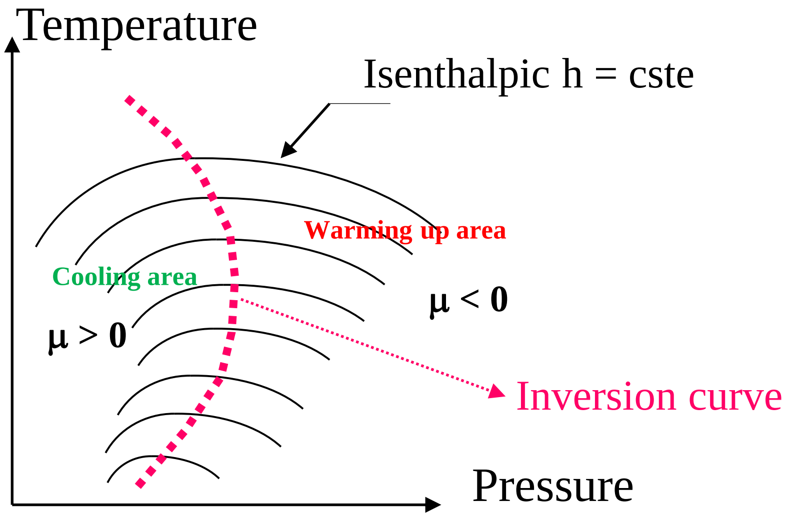
$$\boxed{h_i = h_o}$$

$$dh = C_P dT + (k+V)dP = C_P dP + \left(V - T\left(\frac{\partial V}{\partial T}\right)_P\right) dP = 0$$

where $k = -T\left(\frac{\partial V}{\partial T}\right)_P$

$$\Rightarrow dT = -\frac{V}{C_{p}}\left[1 - \frac{T}{V}\left(\frac{\partial V}{\partial T}\right)_P\right] dP = \frac{V}{C_{p}}(\alpha_V T - 1)dP = \mu_{JT} dP$$

$$\mu_{JT} = \left(\frac{\partial T}{\partial P}\right)_h$$

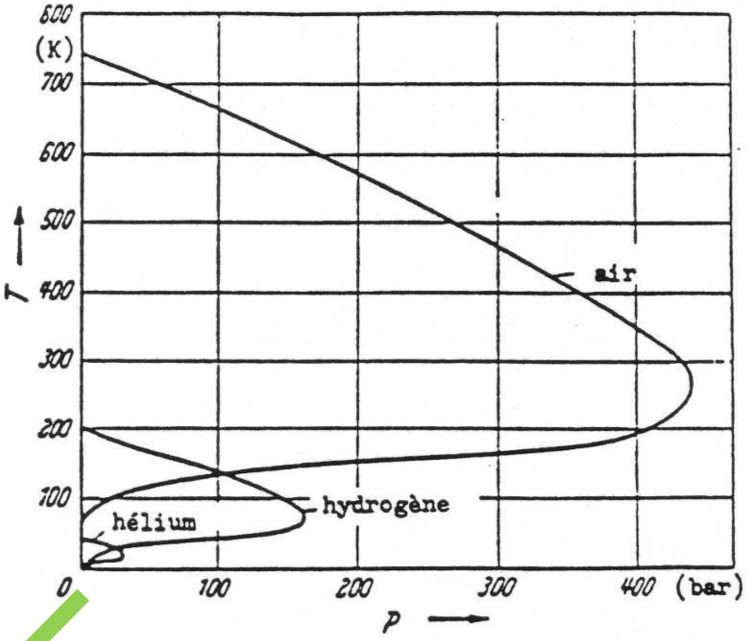


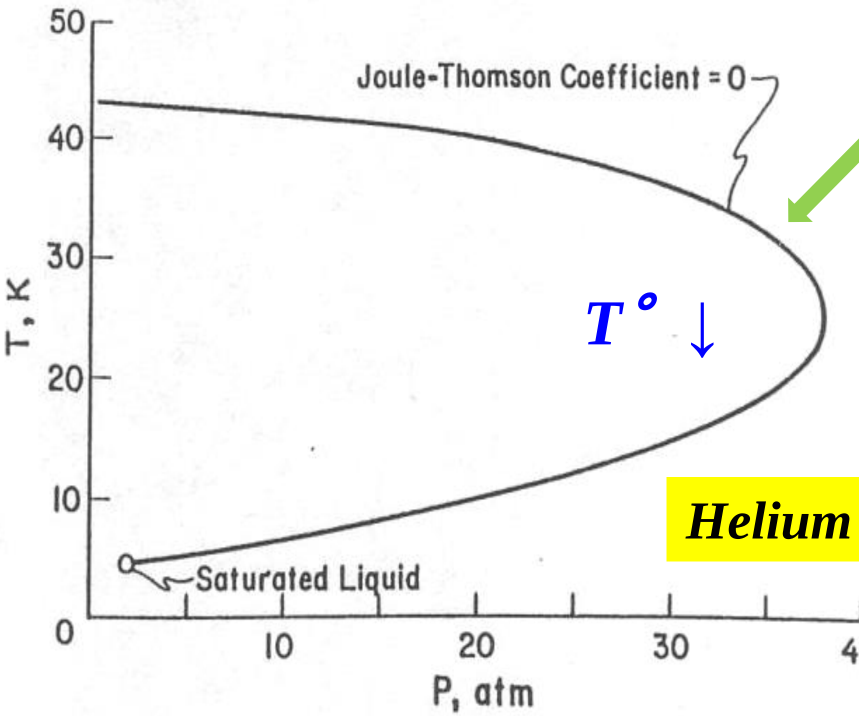
Joule-Thomson Coefficient
> 0 => expansion withT ↓
< 0 => expansion with T ↑

R : μ=0 in perfect gases

Examples of inversion curves

Gas	maximum inversion T° (K)
O2	**761**
Ar	**722**
N2	**622**
Air	**603**
Ne	**250**
H2	**202**
He	**40**





T° ↓

T° ↑

Effect of pressure decreasing

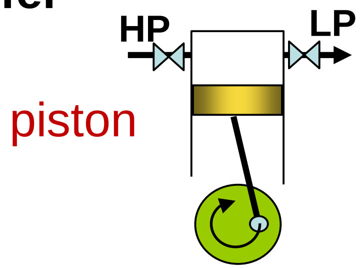
Helium

Strong limitation of cooling effect with a JT expansion in He !

Isentropic expansion

Isentropic expansion (**ideally adiabatic and reversible**)

- obtained with **external recovery of work and no heat transfer**



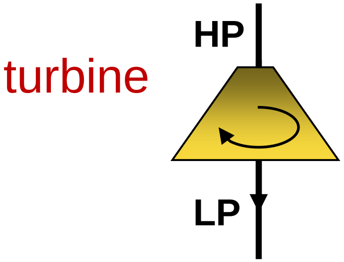
$\Delta Q=0$ and $\Delta W < 0$

$$\boxed{S_i = S_o}$$

$$\delta Q = TdS = C_P dT + k dP = C_P dT - T\left(\frac{\partial V}{\partial T}\right)_P dP = 0$$

with $k=-T\left(\frac{\partial V}{\partial T}\right)_P$

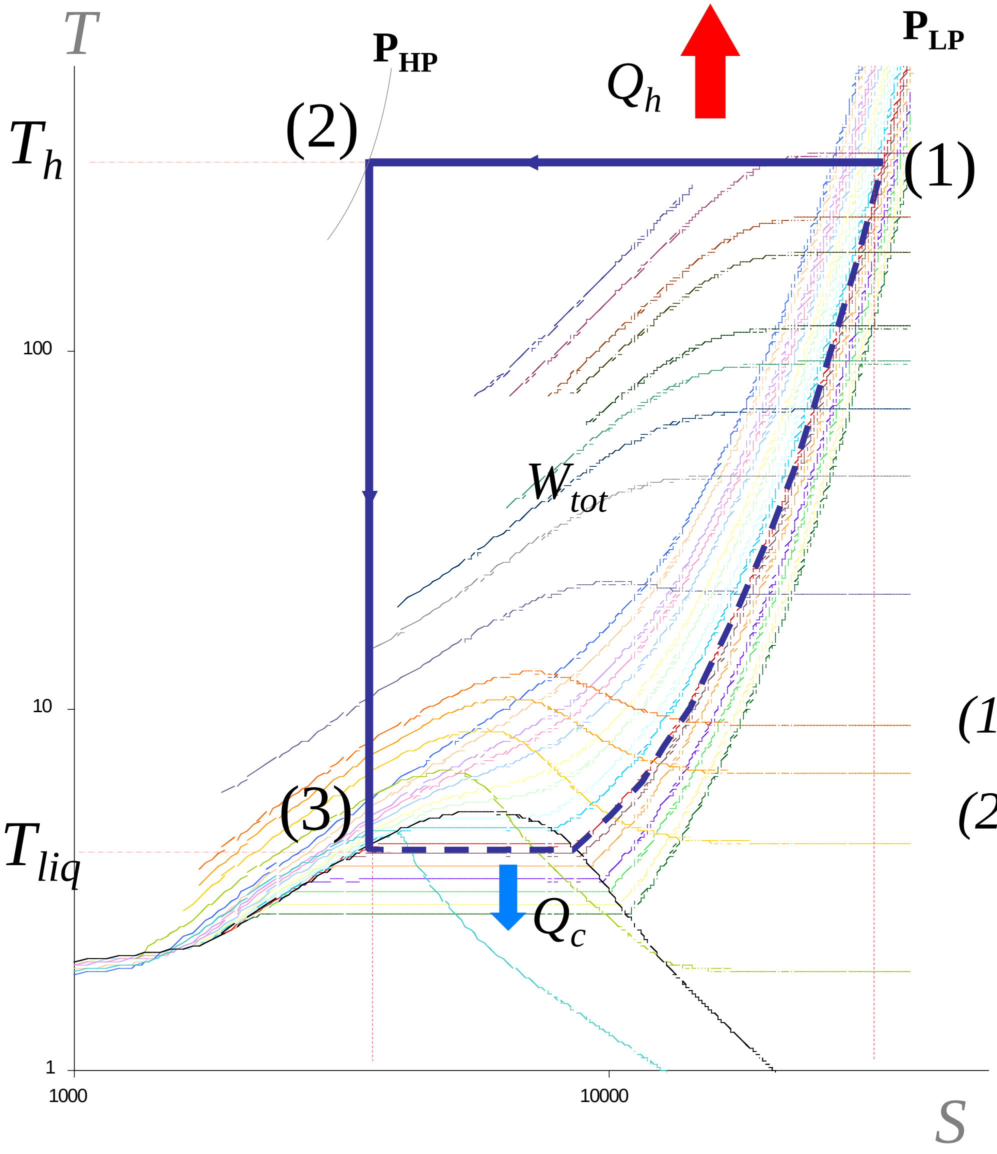
$$=> \ dT = \frac{T}{C_{p}.}\left(\frac{\partial V}{\partial T}\right)_P dP = \frac{V\alpha_V T}{C_{p}.} dP \text{ and } \alpha_V = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$$

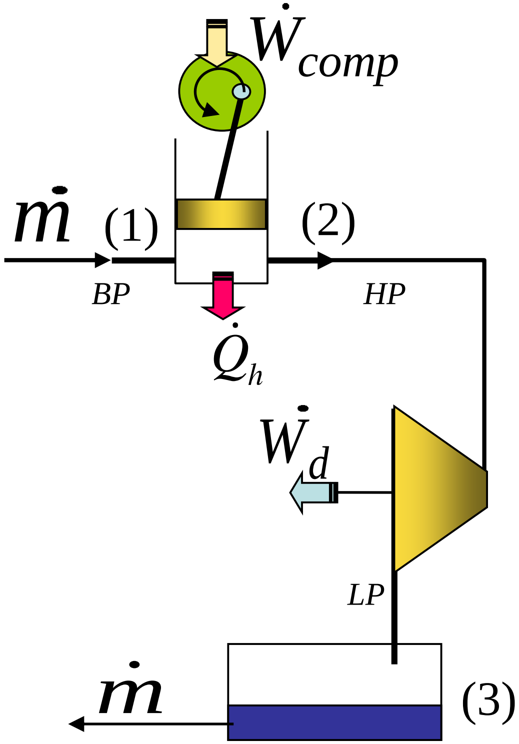


$$m_{DS=0} = \left(\frac{\partial T}{\partial P}\right)_S > 0$$

With an isentropic expansion, the temperature variation is always negative and much larger than for isenthalpic expansion (JT).

The minimum work for liquefying from 300 K and 1 bar (Patm)





(1) -> (2) isothermal compression

(2) -> (3) isentropic expansion

$$Wtot = Q_h - Q_c$$

$$W_{tot}/\dot{m} = T_h \cdot (s_1 - s_3) - (h_1 - h_3)$$

Ideal liquefaction (real gases)

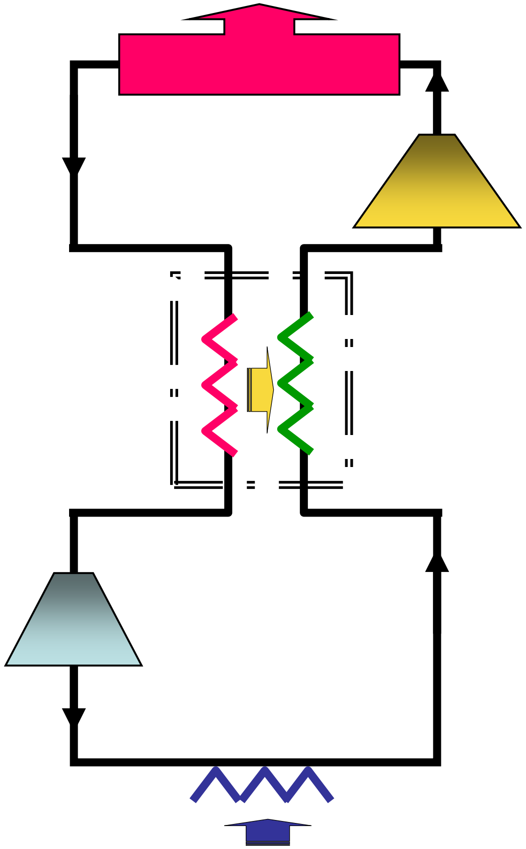
(from Patm)

Fluid	Boiling temperature at 1 atm (K)	$W_{tot} = W_{ideal}$ (J/g)	$W_{tot} = W_{ideal}$ (W/(l/h))
Oxygen (O_2)	90	634	202
Argon (Ar)	87	476	188
Air	80	722	176
Nitrogen (N_2)	77	761	171
Hydrogen (H_2)	20,4	11890	231
Helium (He)	**4,2**	**6807**	**236**

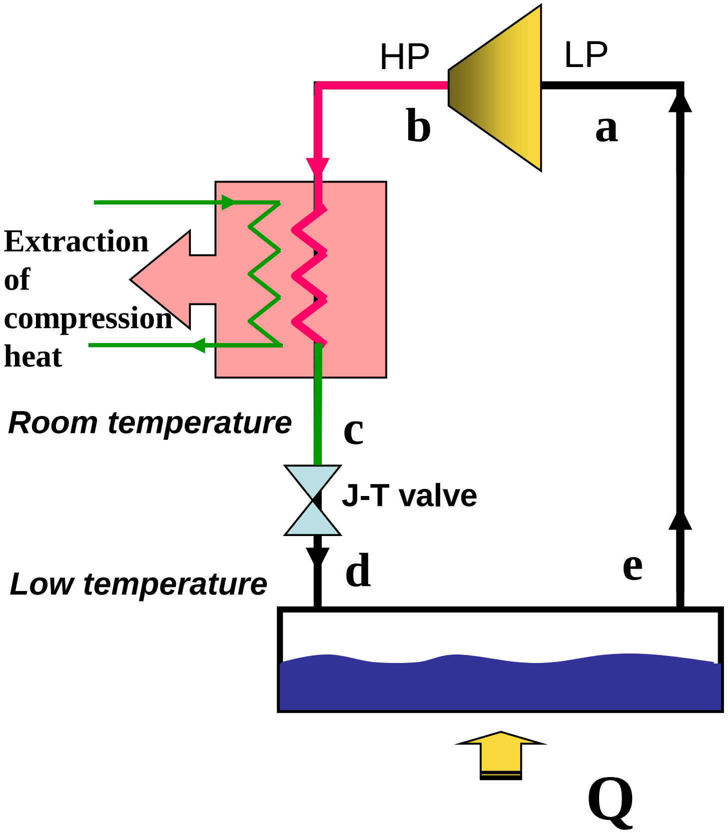
Ideal but not realistic (too high pressure and impossible perfect isentropic on a large ΔT)

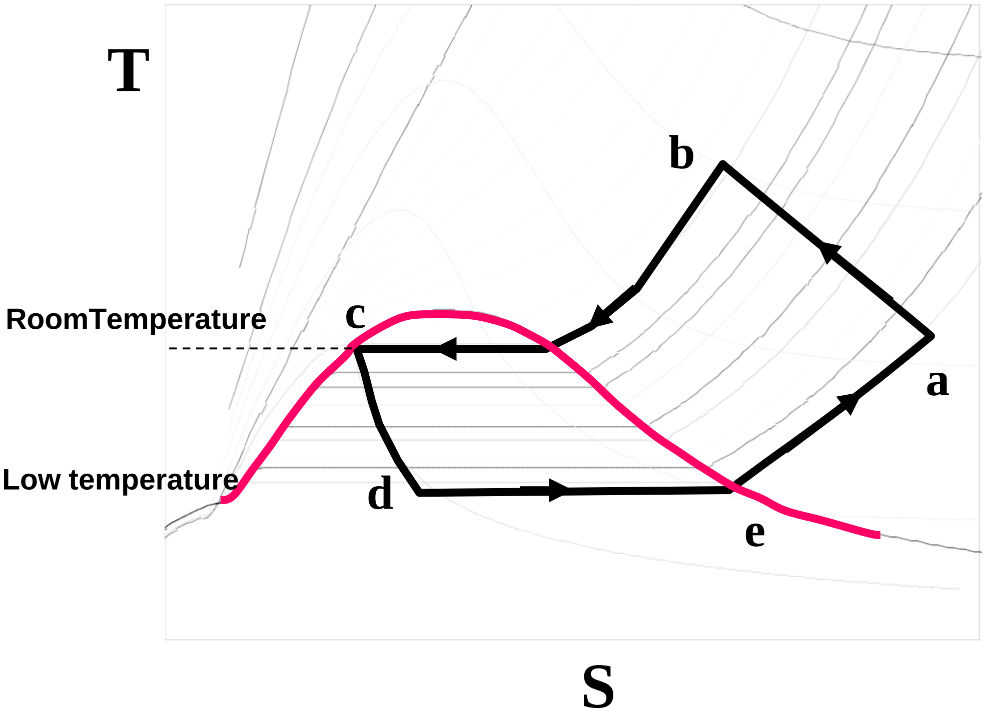
Ex : Helium High Pressure needed = 10^6 atm !!!!

Realistic continuous flux gas cycles



Vapor compression cycle

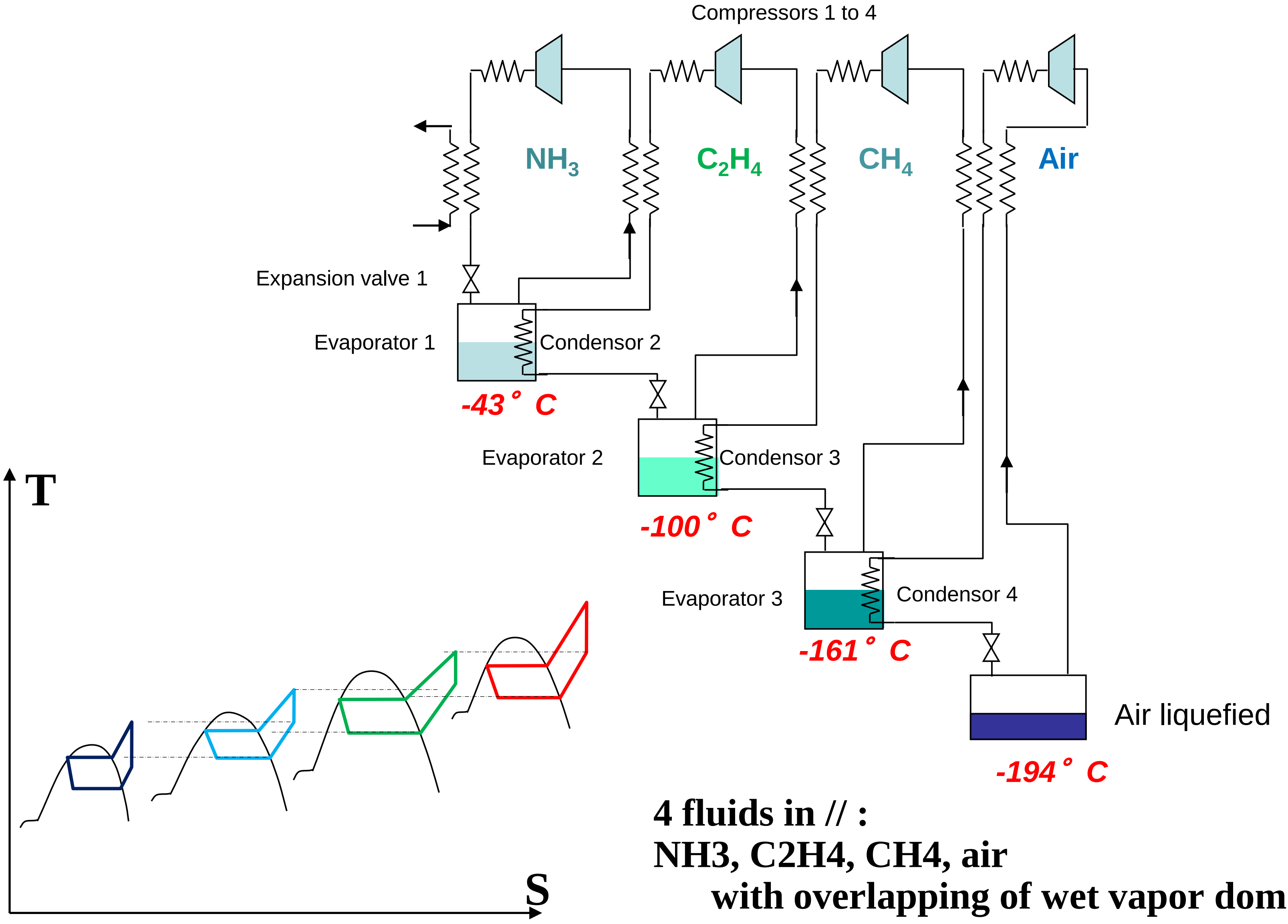




Used in « industrial or domestic » refrigeration process but limited in range due to :

- Low temperature difference reachable in wet vapor between triple and critical points
- Necessity of using a refrigerant fluid with a saturation temperature close to the room temperature (compressor)

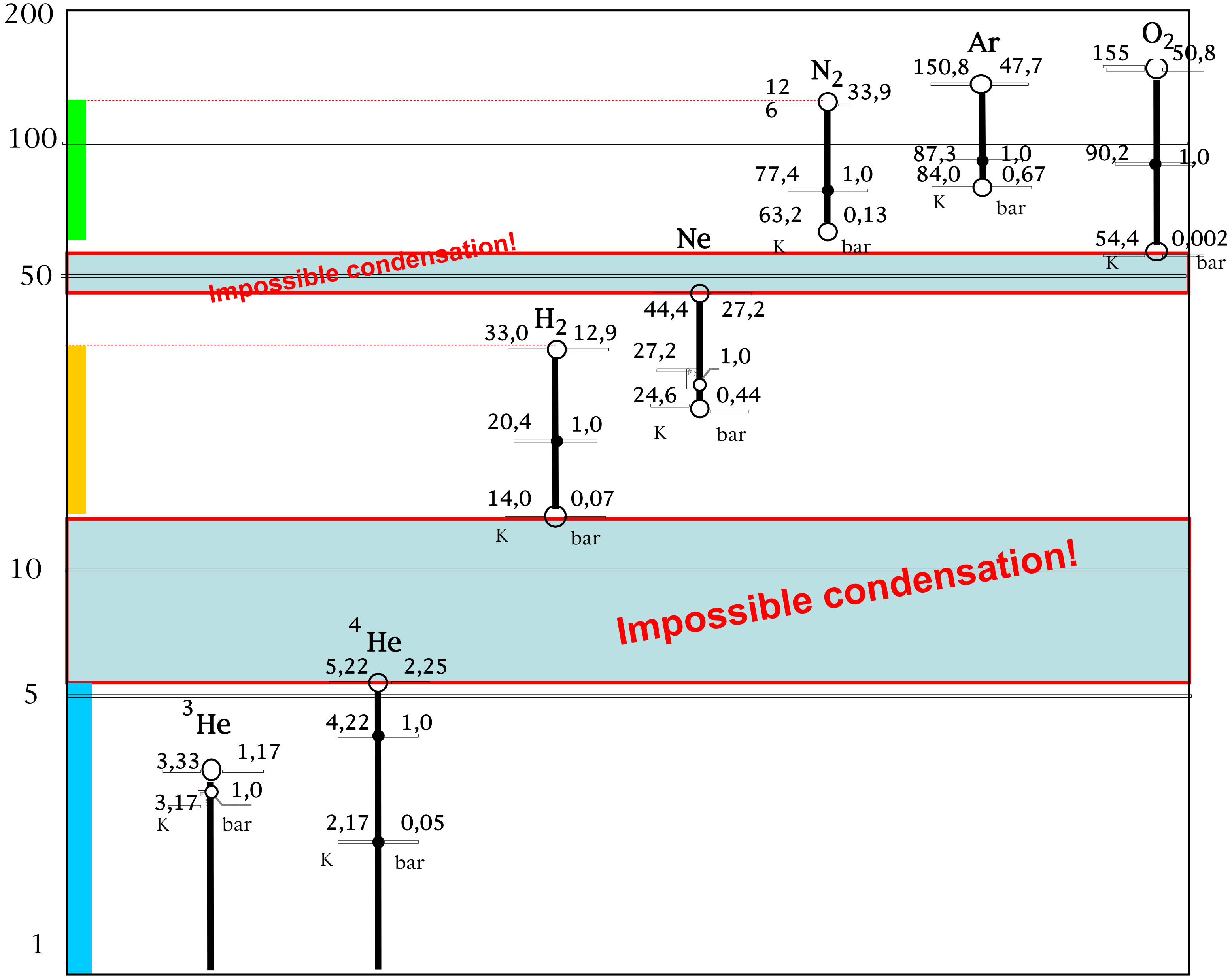
Compression vapor cycle in cascading



4 fluids in // :
NH3, C2H4, CH4, air
with overlapping of wet vapor domains

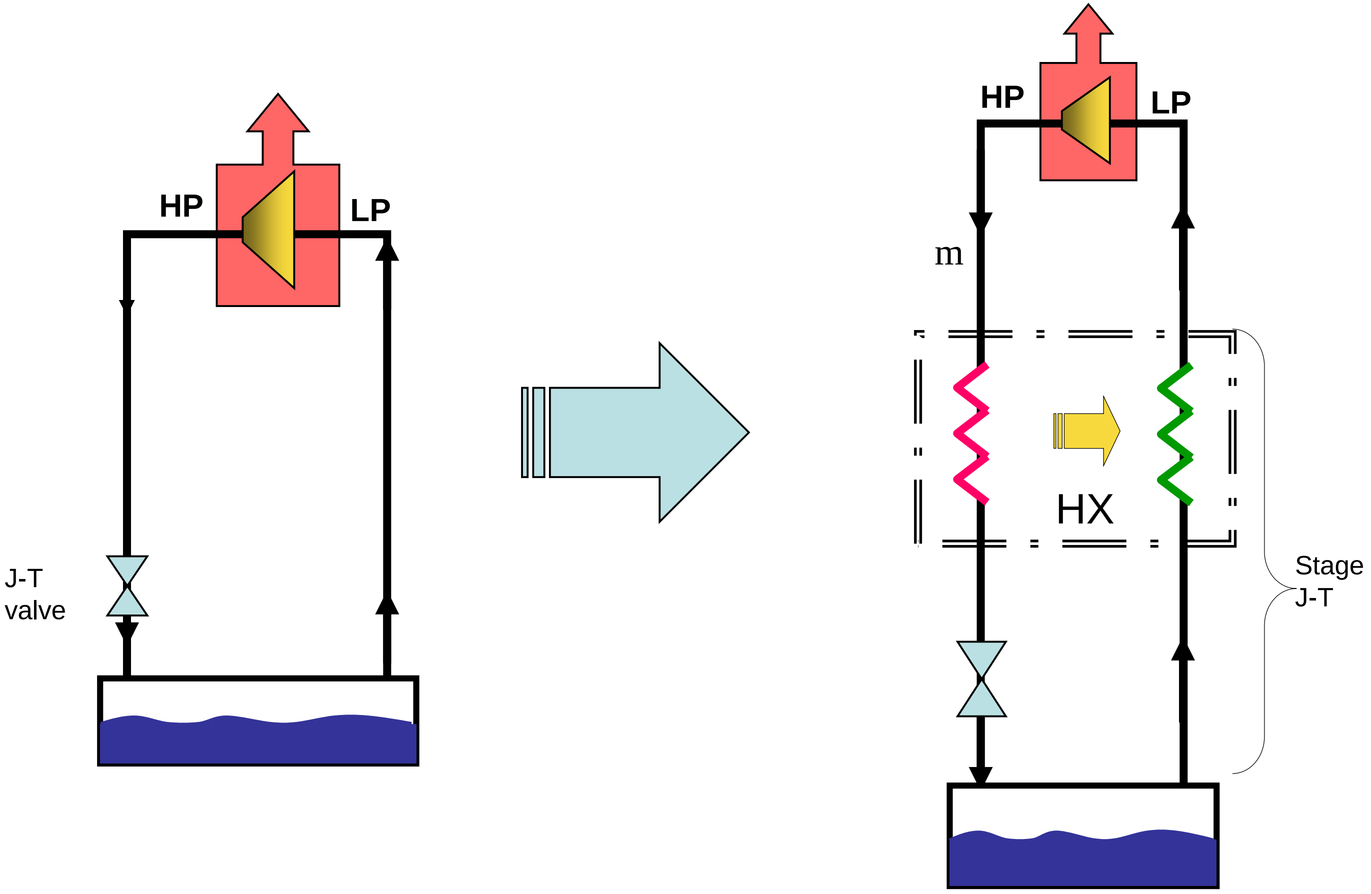
T in K

Cryofluid range with « no liquid » areas



Linde-Hampson cycle : recovering cold gas enthalpy

Joule-Thomson expansion (adiabatic without external work =isenthalpic)
+ ***recuperative heat exchanger*** *(counterflow)*



Linde-Hampson cycle :

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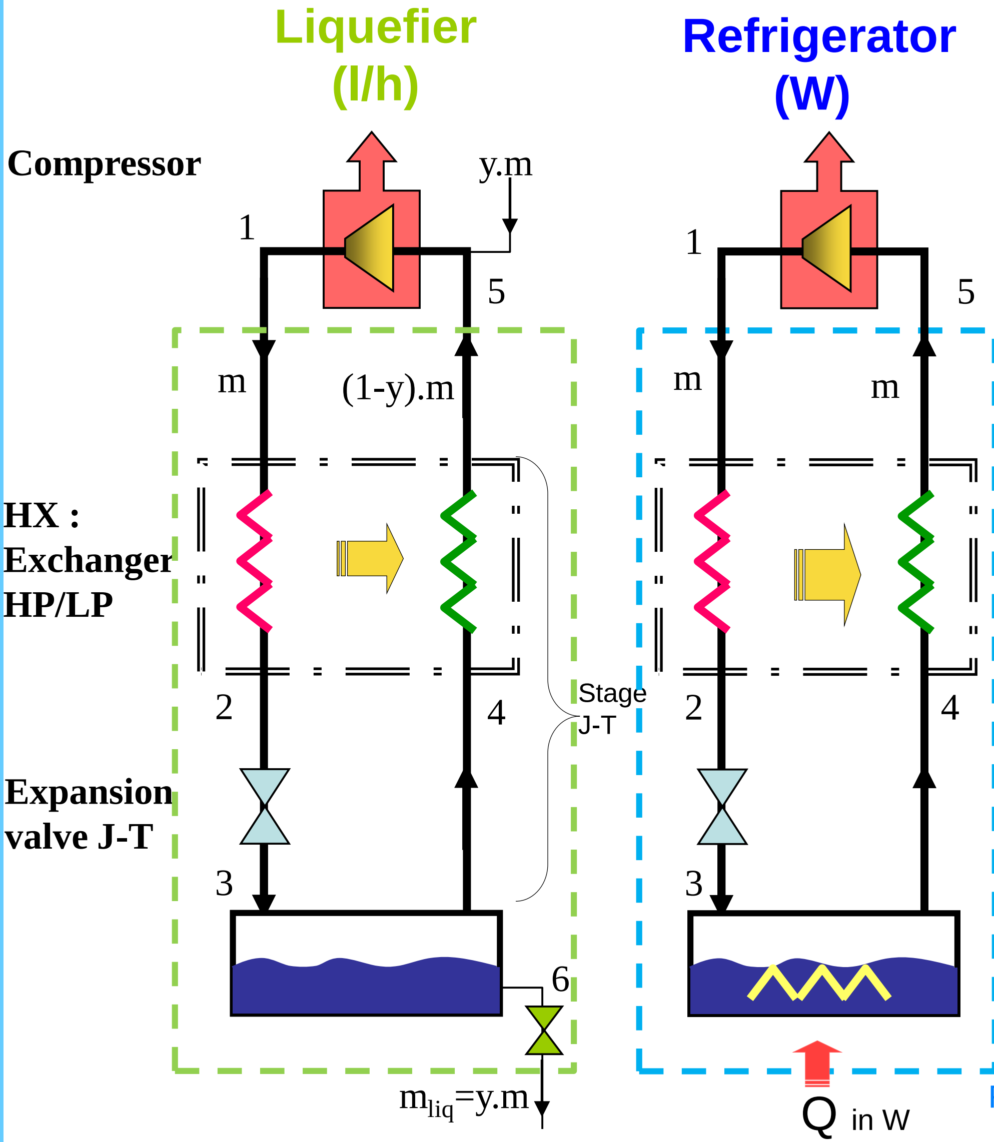
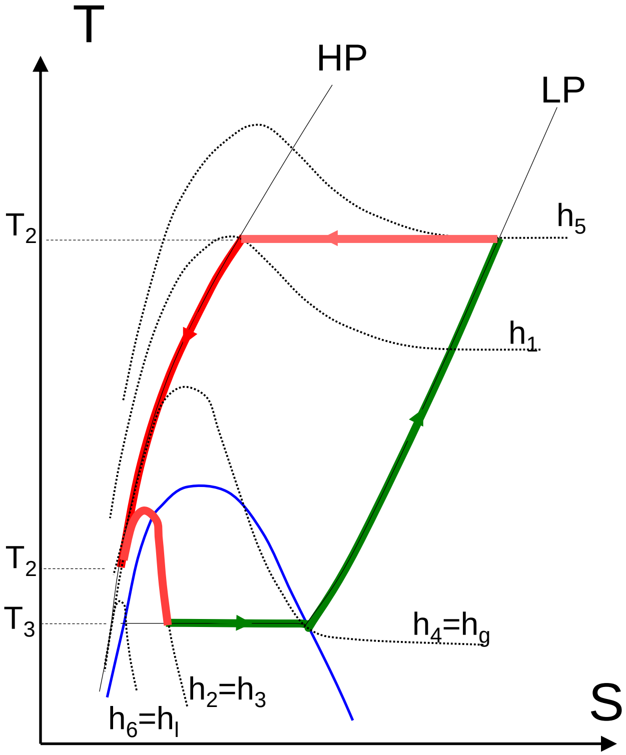




Liquefaction mode

$$\dot{m} \times h_1 = \left(\dot{m} - \dot{m}_{liq}\right) \times h_5 + \dot{m}_{liq} \times h_{liq}$$

$$y = \frac{\dot{m}_{liq}}{\dot{m}} \quad \text{Þ} \quad y_{liqué} = \frac{\left(h_5 - h_1\right)}{\left(h_5 - h_{liq}\right)}$$

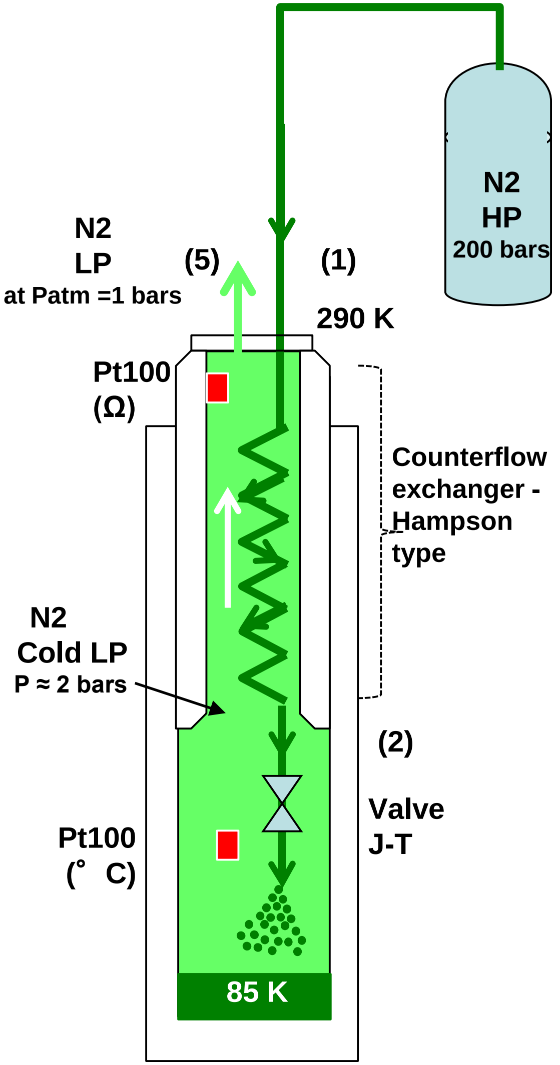
Refrigeration mode

$$Q_{ref} = \dot{m} \times (h_5 - h_1) = \dot{m} \times (h_{gaz} - h_3)$$

$$\text{Þ} \quad y_{réfrig} = \frac{\left(h_5 - h_1\right)}{\left(h_{gaz} - h_{liq}\right)} > y_{liqué}$$

Linde-Hampson cycle for Nitrogen

- Compressor 200 atm (or HP cylinder
- Counterflow heat exchanger
- Expansion valve



Vacuum insulated cryostat

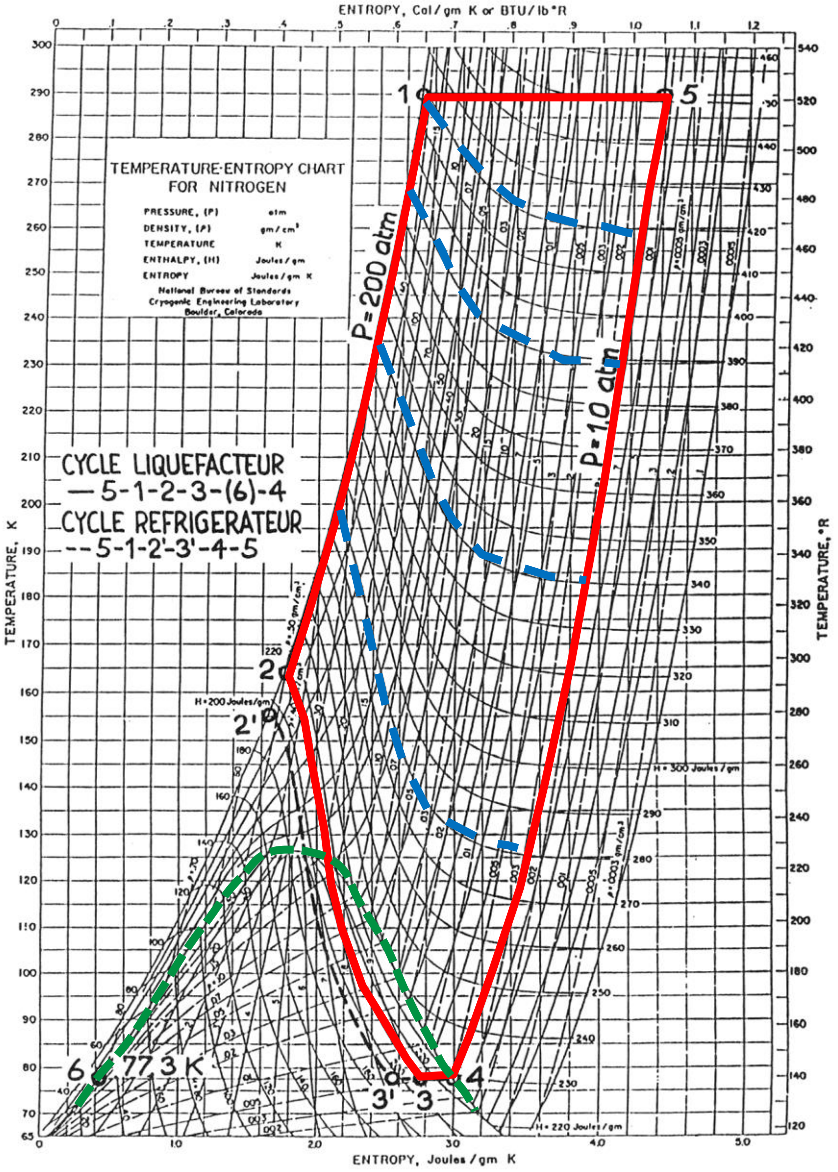
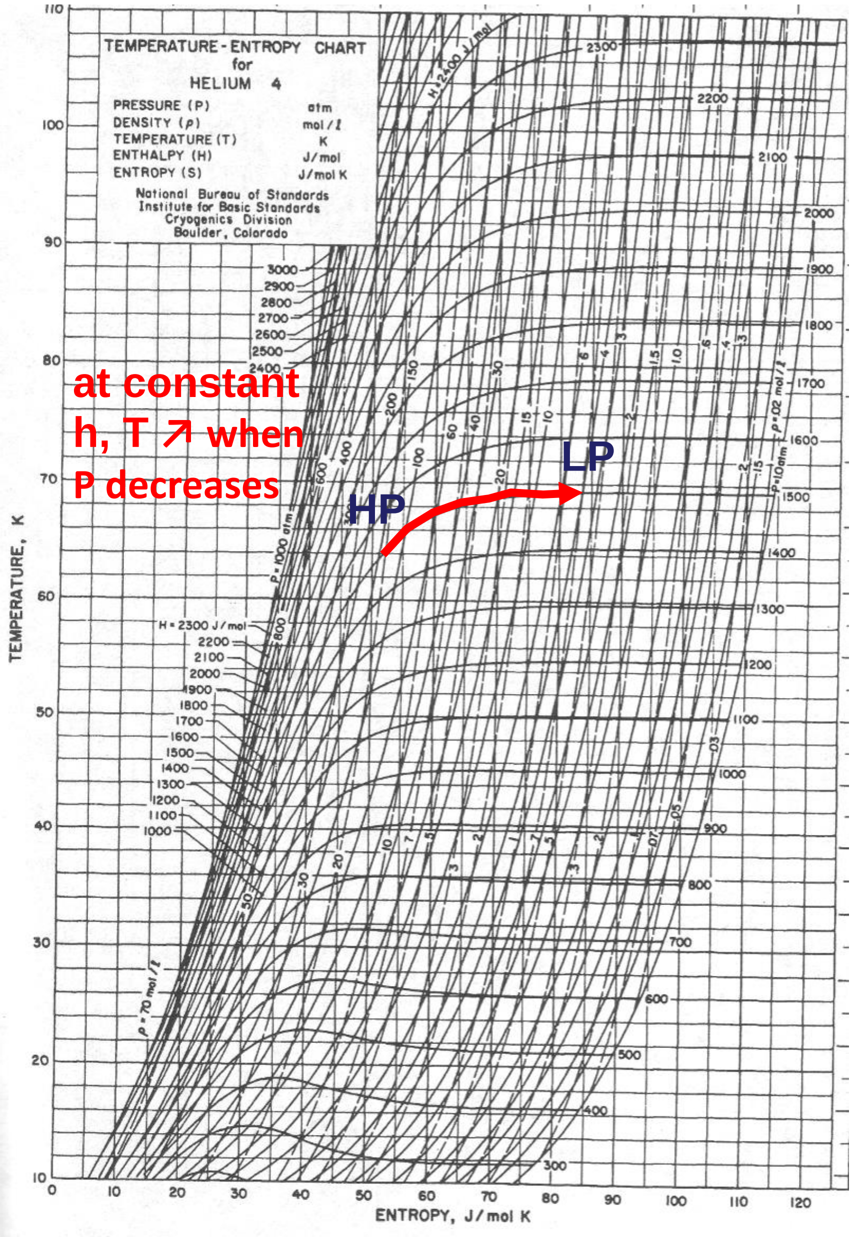


FIG. 9.3.4. : CYCLE DE LINDE (REFRIGERATEUR ET LIQUEFACTEUR)
AU DIAGRAMME TEMPERATURE-ENTROPIE

pour P_1 = 200 ata T_1 = 290 K
P_5 = 1 ata T_5 = 290 K

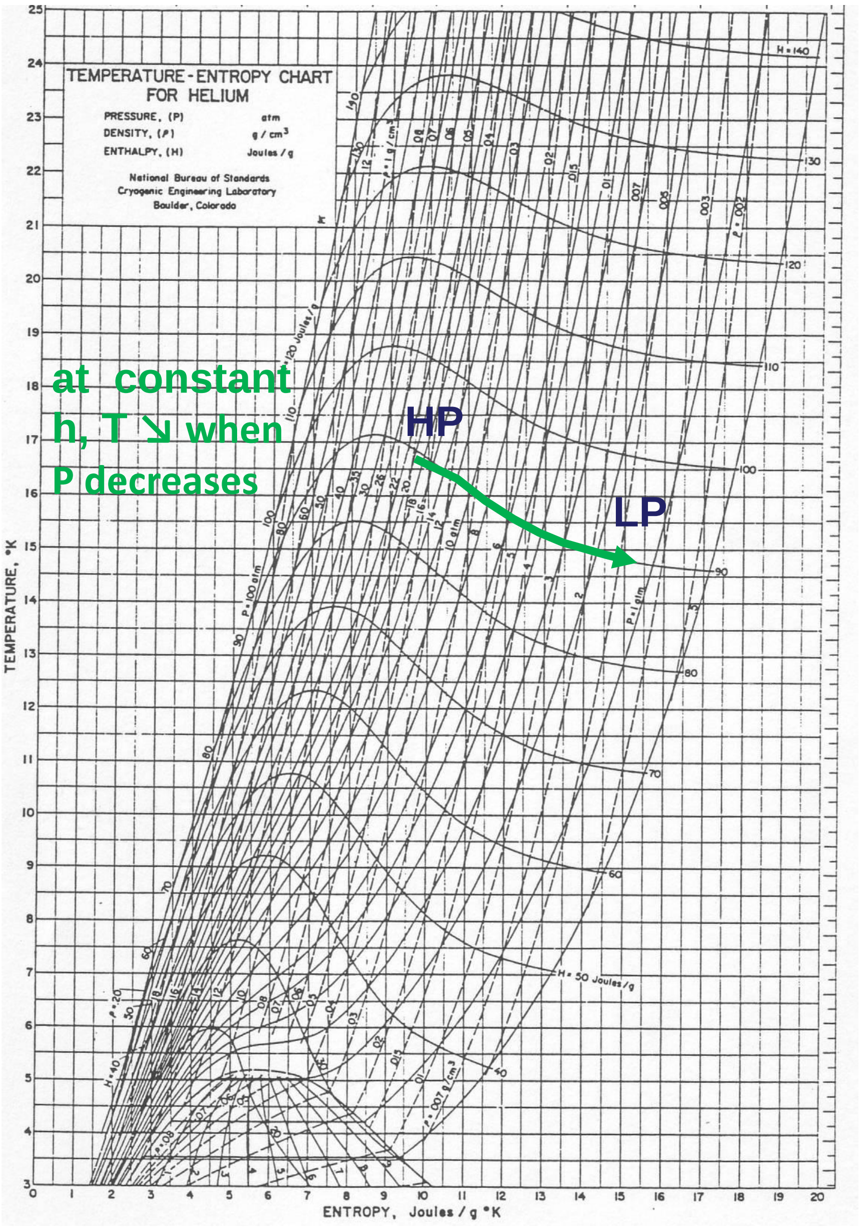
Impossibility of single Linde-Hampson cycle 300-4 K for helium



at constant h, T ↗ when P decreases

HP

LP



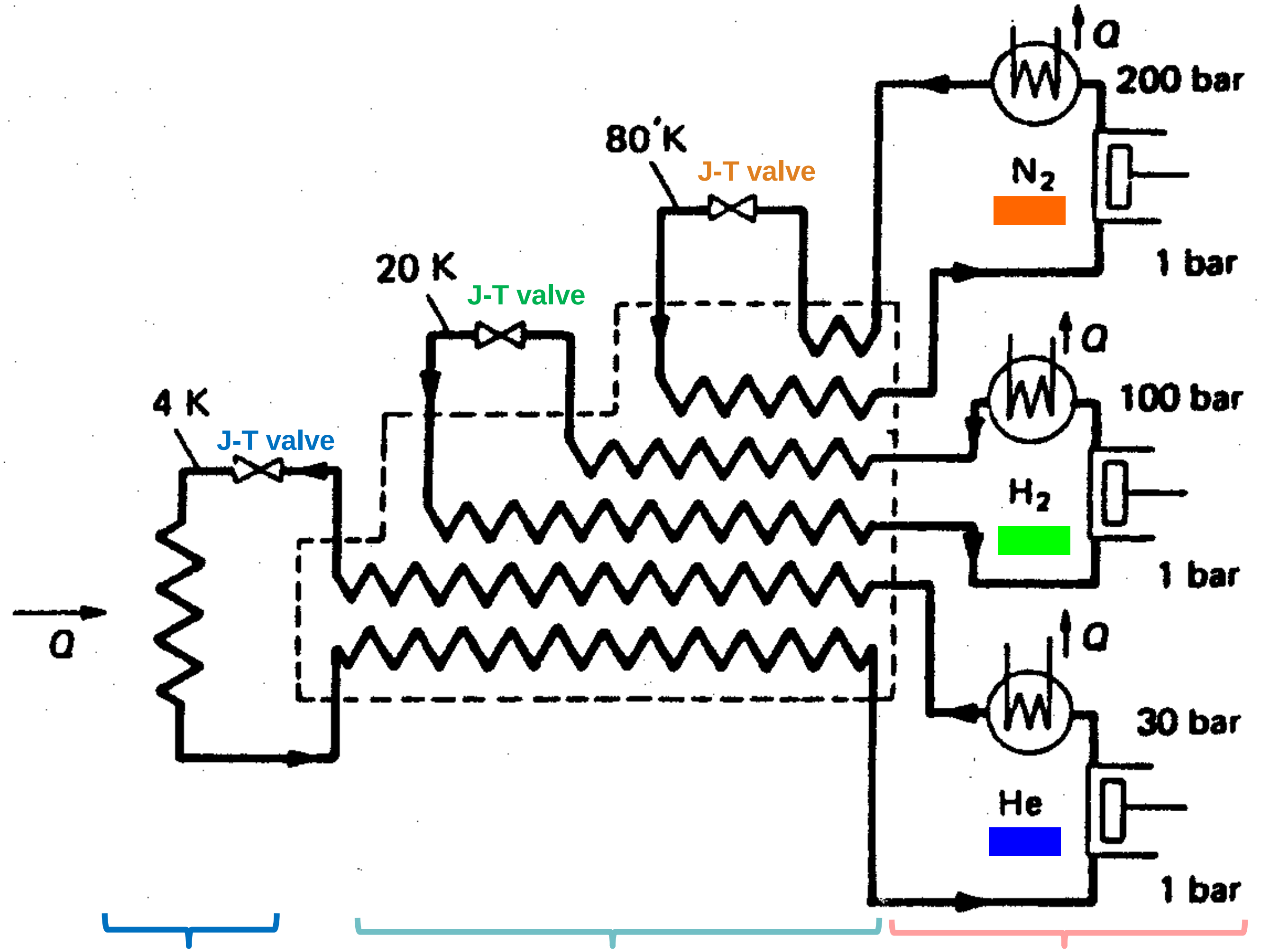
at constant h, T ↘ when P decreases

HP

LP

For He : Cycle Linde-Hampson cycle in cascading

Historically, to reach helium liquid temperature...

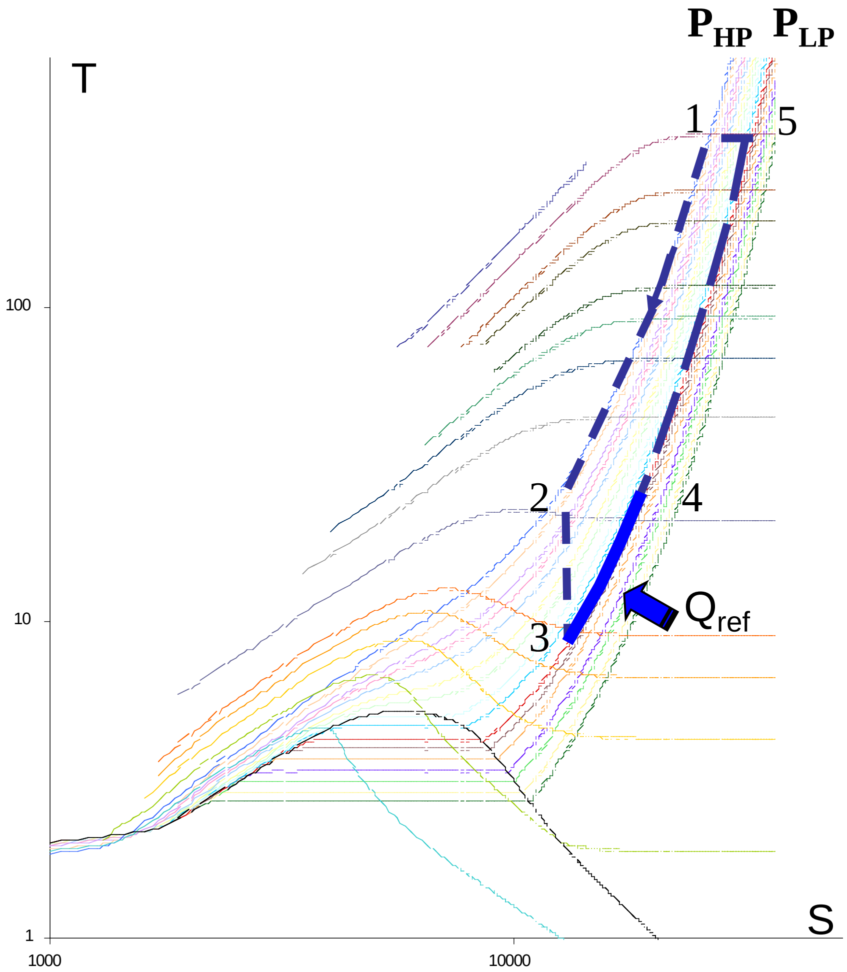


Cold source at 4 K **Multi Heat exchangers** **Compressors**

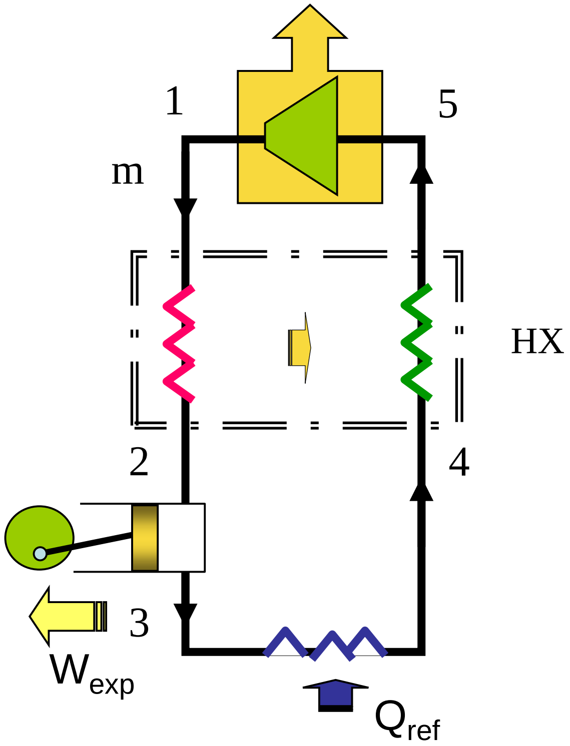
Courtesy of S Buhler

Brayton cycle : replace JT valve by a work recuperative expander

Adiabatic expansion with work to be supplied= isentropic + recuperative heat exchanger



R : Refrigerator at variable T°



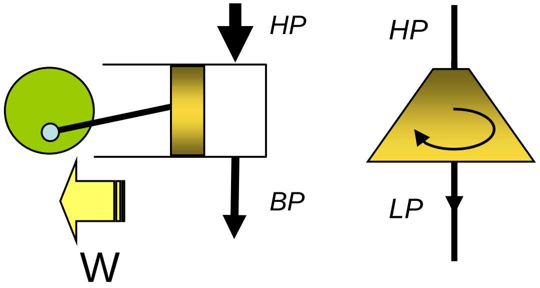
$$W_{exp} = m \times (h_2 - h_3)$$

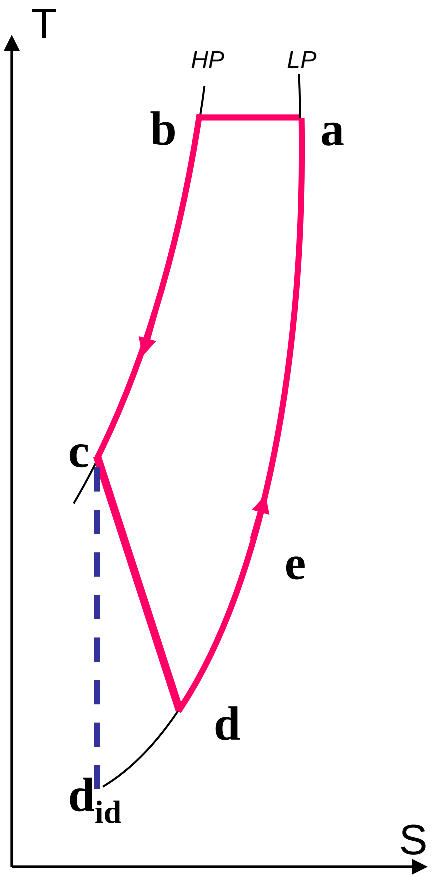
$$Q_{ref} = m \times (h_4 - h_3)$$

Isentropic expansion or nearly...

Isentropic efficiency of an expansion device

$$\eta_{\text{isen}} = \frac{h_d - h_c}{h_{d_{id}} - h_c}$$





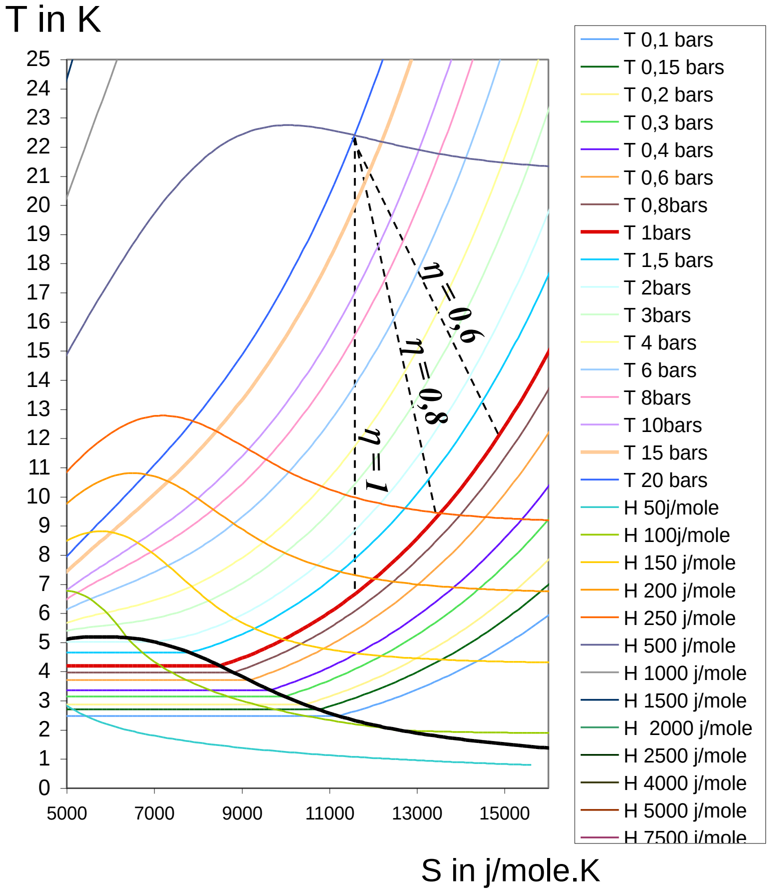
A.N : Helium

T_{HP}=22,4 K and P_{HP} = 20 bars and P_{BP} = 1 bar

η = 1 (perfect isentropic)
T= 6,6 K
(h=46,6 J/g)

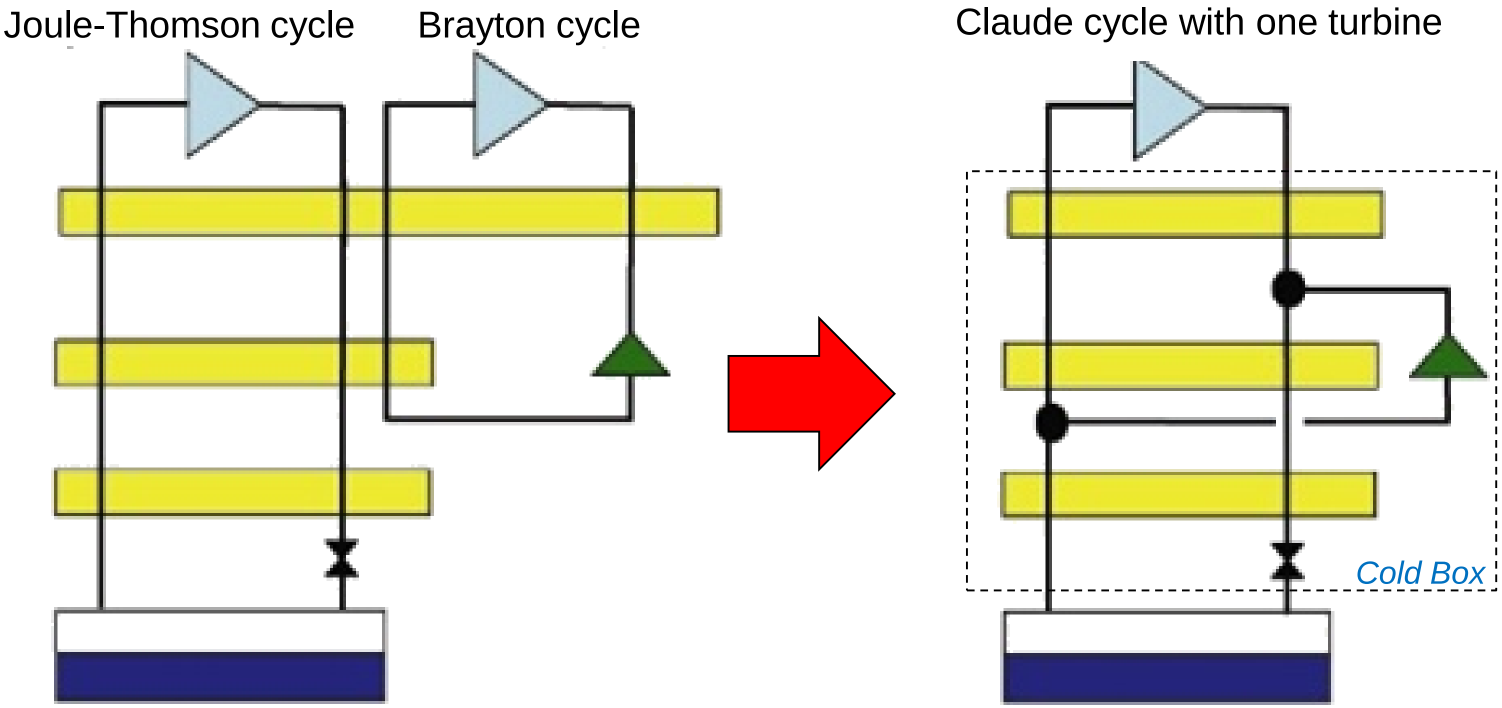
η= 0,8
T=9,3 K
(h=62,0 J/g)

η= 0,6
T=12,2 K
(h=77,4 J/g)



Claude cycle

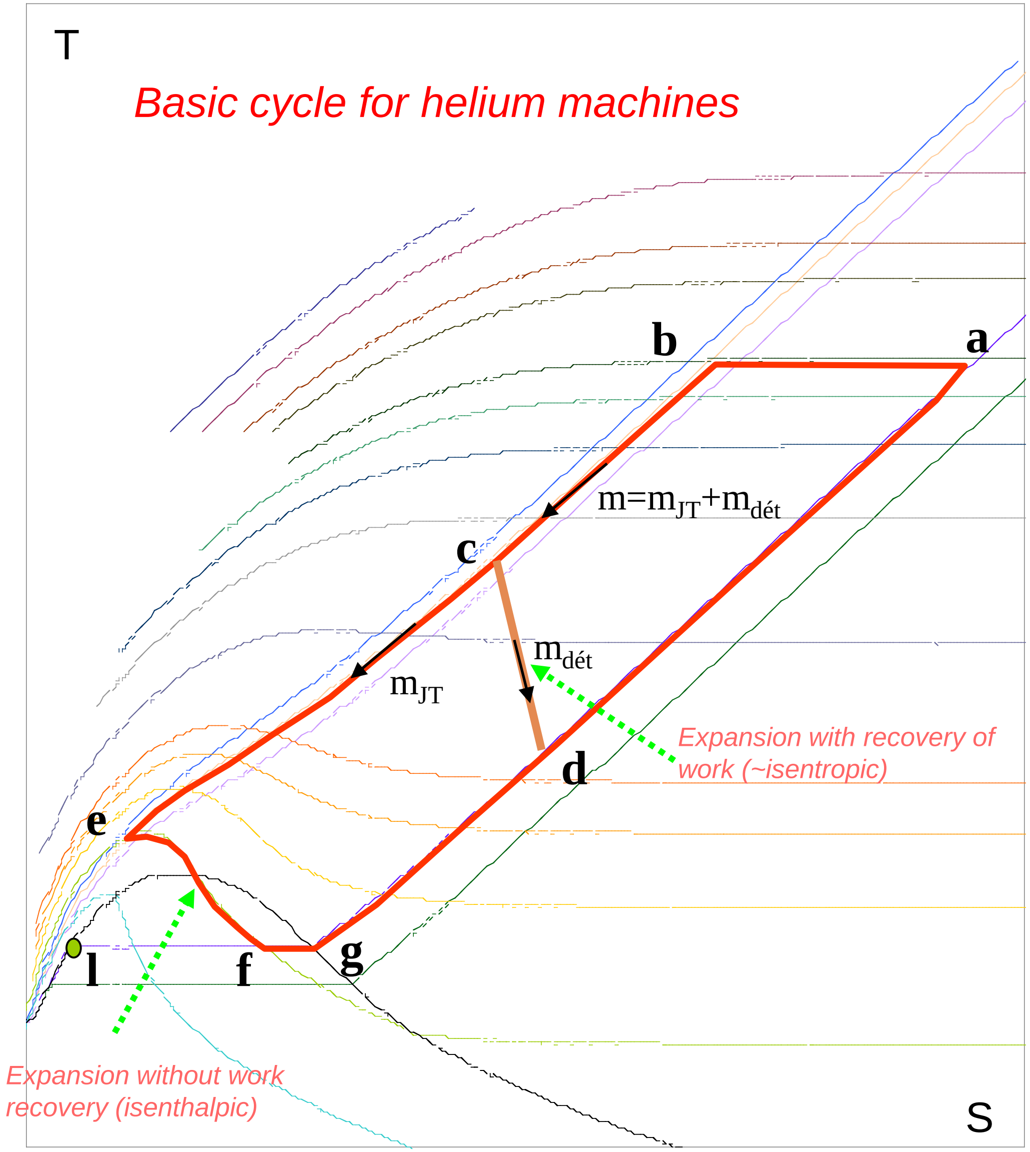
Mixing of Brayton cycle and Joule-Thomson cycle

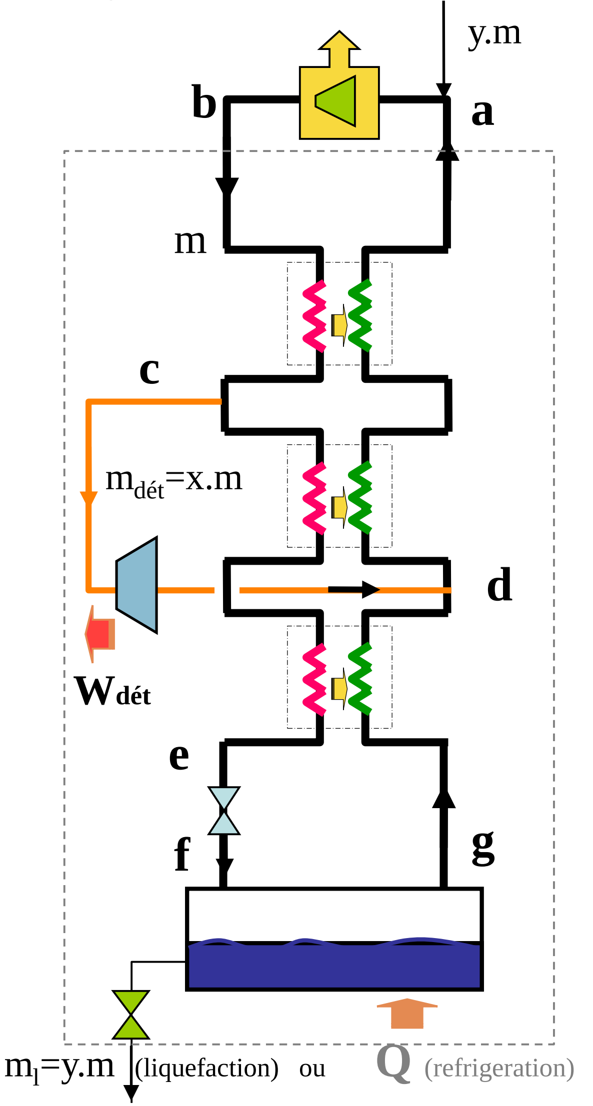


One fluid, one compressor,
2 types of expansion !!!
The principle of cycle used today for large refrigeration or liquefaction

Claude cycle

Mixing a Brayton cycle and Joule-Thomson cycle

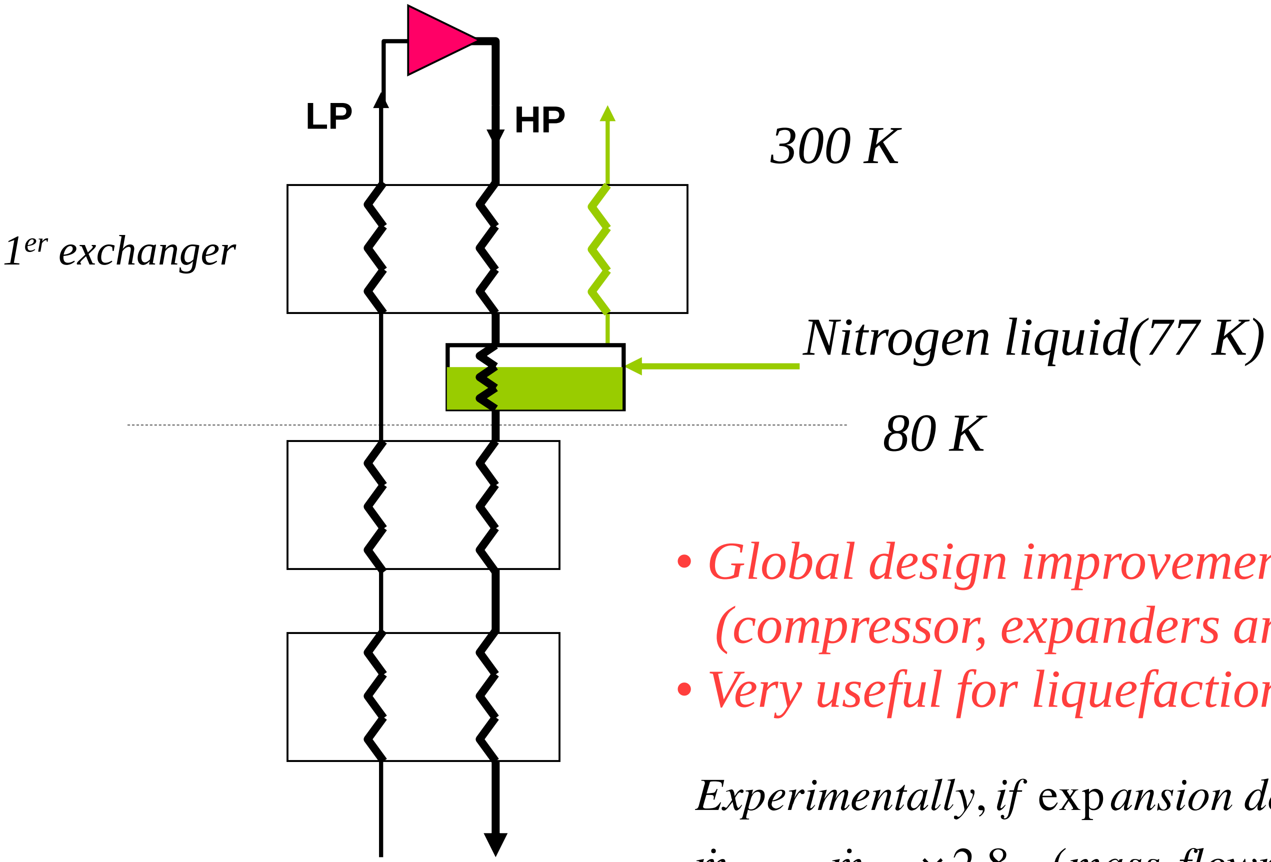




Ideal rate liquefaction

$$y = \frac{h_a - h_b}{h_a - h_l} + x \times \frac{h_c - h_d}{h_a - h_l}$$

Nitrogen pre-cooling in the top of a Cold Box (Helium cycle)



- *Global design improvement by size reducing (compressor, expanders and exchangers)*
- *Very useful for liquefaction*

$$Experimentally, if \; \exp ansion \; devices < 80\,K:$$

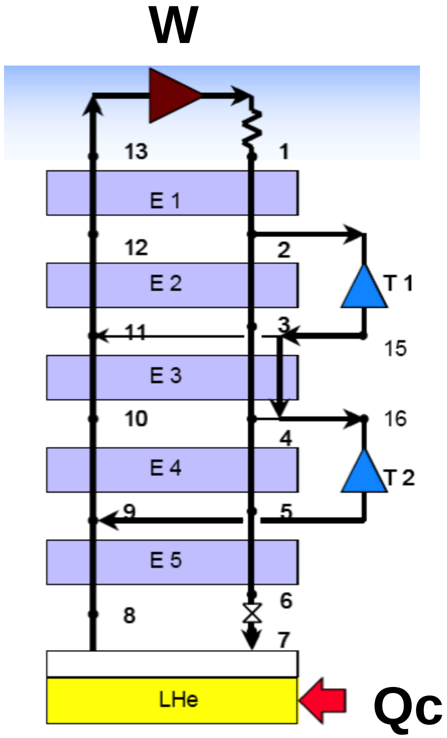
$$\dot{m}_{LN2} \approx \dot{m}_{LHe} \times 2.8 \quad (mass \;\; flowrate)$$

ratio of liquid flows

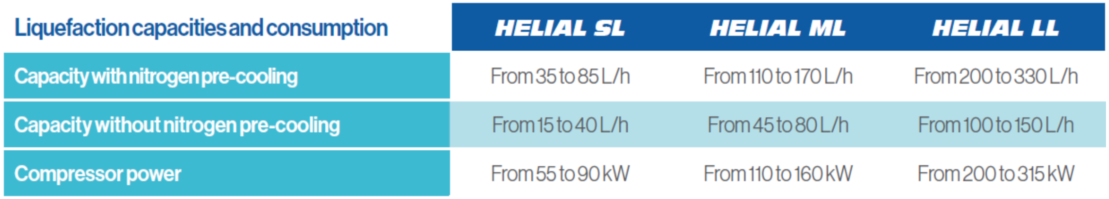
$$\dot{V}_{LN2} \approx \dot{V}_{LHe} \times 0.43 \quad (volume\; rate)$$

Examples of machines : « small » He refrigerator/liquefier

From a few tenth to hundred of W @ 4.5 K (Qc) : 1 to 2 turboexpanders (turbines) + 1 JT valve

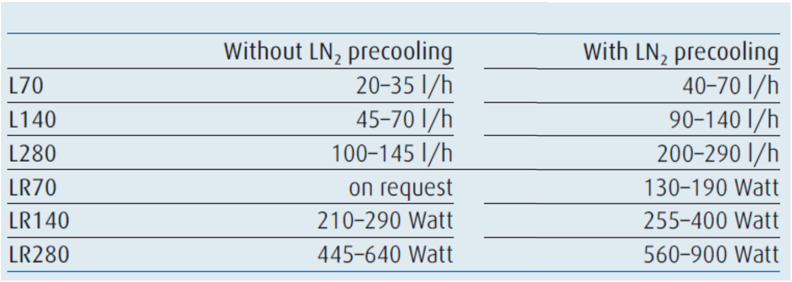


Commercial data from **Air Liquide**



Liquefaction capacities and consumption	HELIAL SL	HELIAL ML	HELIAL LL
Capacity with nitrogen pre-cooling	From 35 to 85 L/h	From 110 to 170 L/h	From 200 to 330 L/h
Capacity without nitrogen pre-cooling	From 15 to 40 L/h	From 45 to 80 L/h	From 100 to 150 L/h
Compressor power	From 55 to 90 kW	From 110 to 160 kW	From 200 to 315 kW

Commercial data from **Linde Kryotechnik**



	Without LN_2 precooling	With LN_2 precooling
L70	20–35 l/h	40–70 l/h
L140	45–70 l/h	90–140 l/h
L280	100–145 l/h	200–290 l/h
LR70	on request	130–190 Watt
LR140	210–290 Watt	255–400 Watt
LR280	445–640 Watt	560–900 Watt

Specific power (W/Qc)

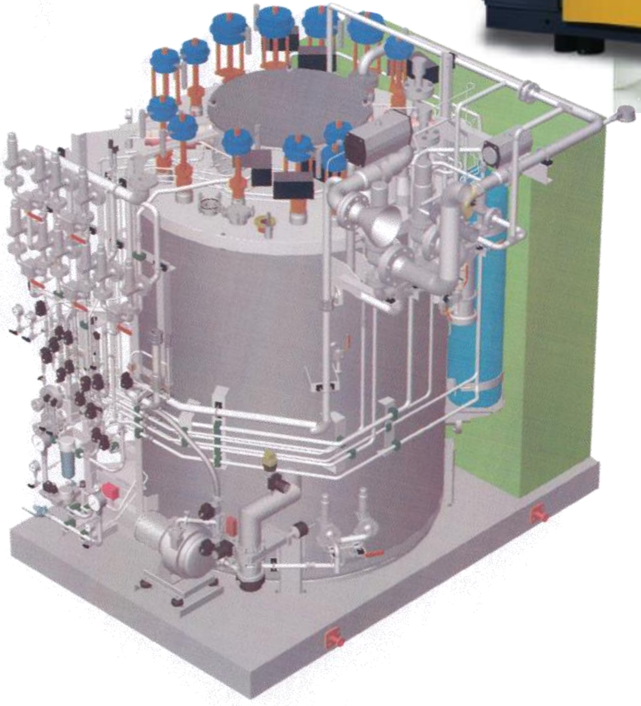
> 500 W/W

R : Carnot = 70 W/W

Examples of machines : « small » He refrigerator/liquefier

Compressor (69 g/s)

Cold Box
Helial 2000
(500 W or 150 l.h^{-1})



Cold Box Helial 2000

L'Air Liquide

Examples of machines : « small » He refrigerator/liquefier

Neurospin helium refrigerator (for 11.7 T MRI magnet)

Turbo-expander

Adsorber pot

Heat exchangers

Dedicated PLC for fully automatic operation

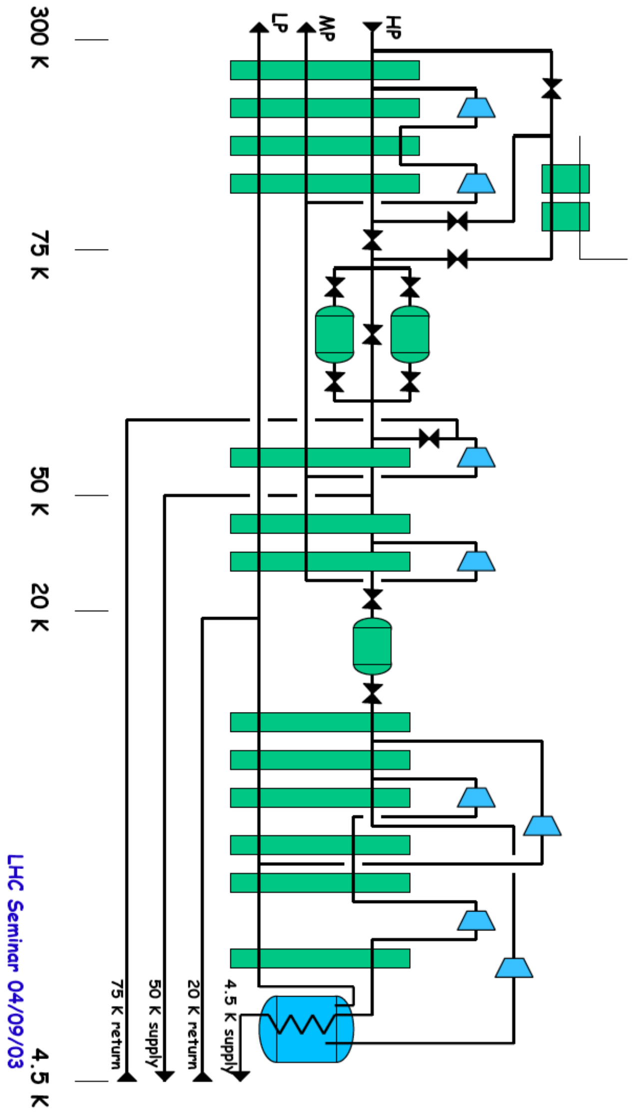
200 W (ref) or 120 l/h (liq) or 70 l/h+ 40 W (mixed)
With a compressor 45 g/s @ 15 bars

Opened Cold Box without its vacuum vessel

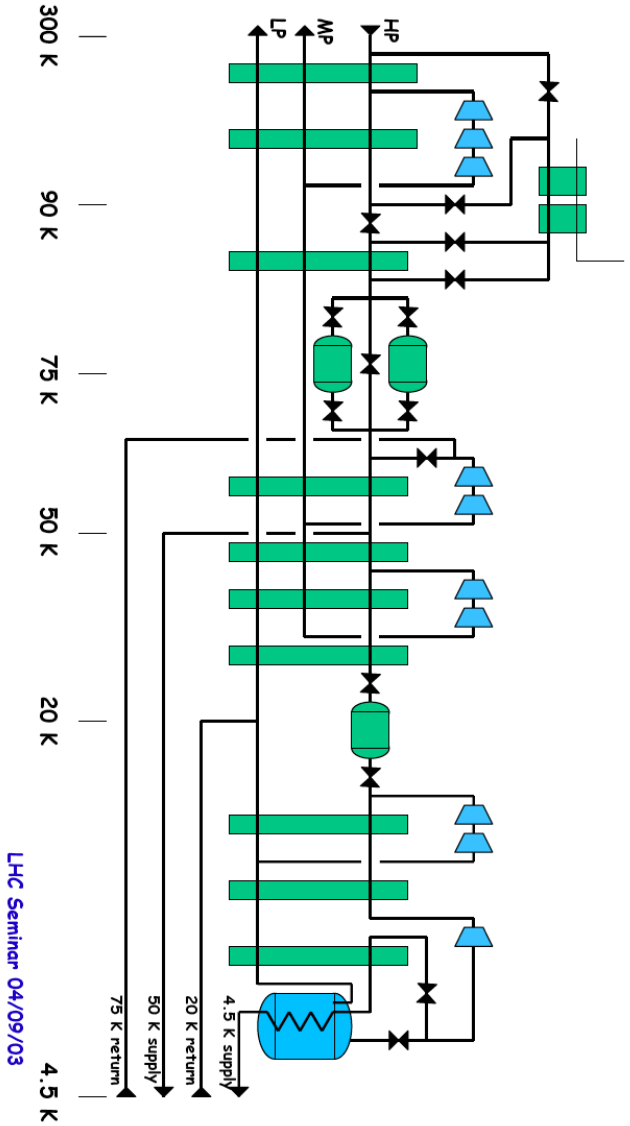
Examples of machines : large Helium Refrigeration

Ex : Cold Box LHC 18 kW @ 4.5 K Refrigerators

Air Liquide

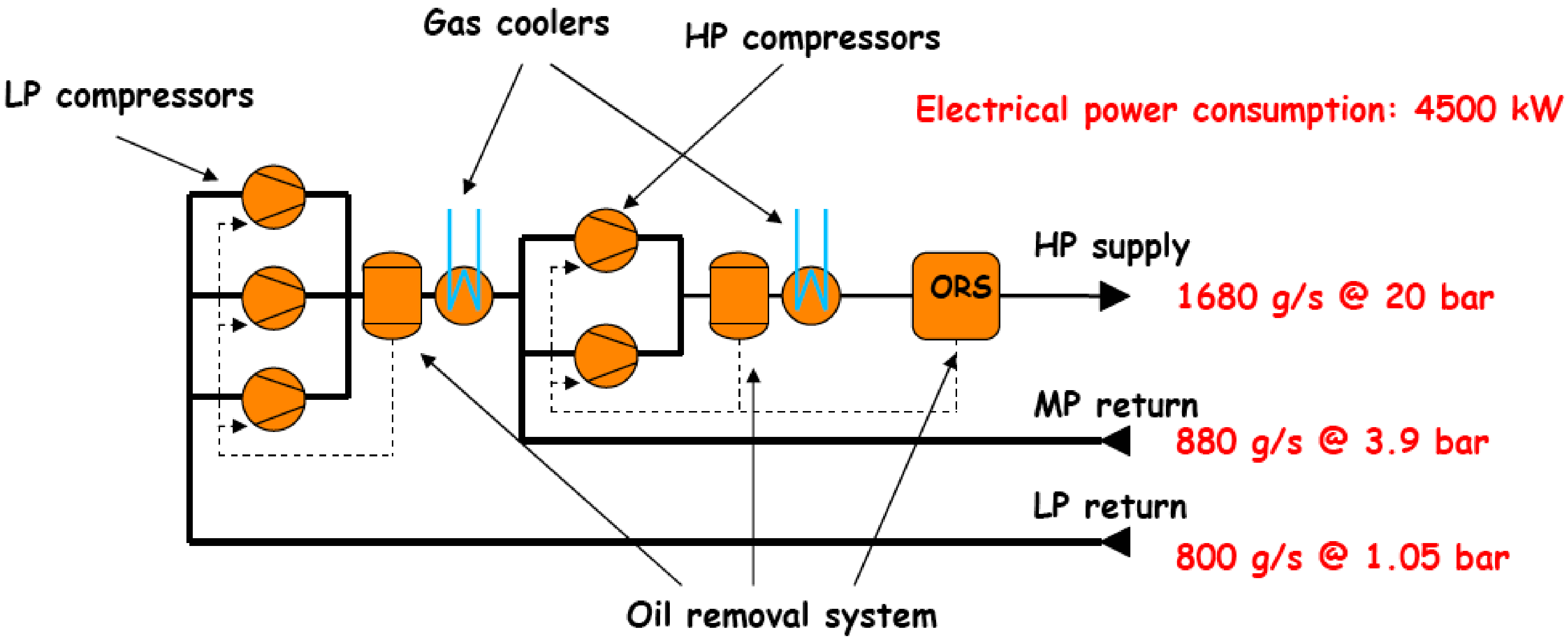


Linde Kryotechnik



Examples of machines : large Helium Refrigeration

Compression unit for a refrigerator 18 kW @ 4,2 K



Gas coolers

HP compressors

LP compressors

Electrical power consumption: 4500 kW

HP supply

1680 g/s @ 20 bar

MP return

880 g/s @ 3.9 bar

LP return

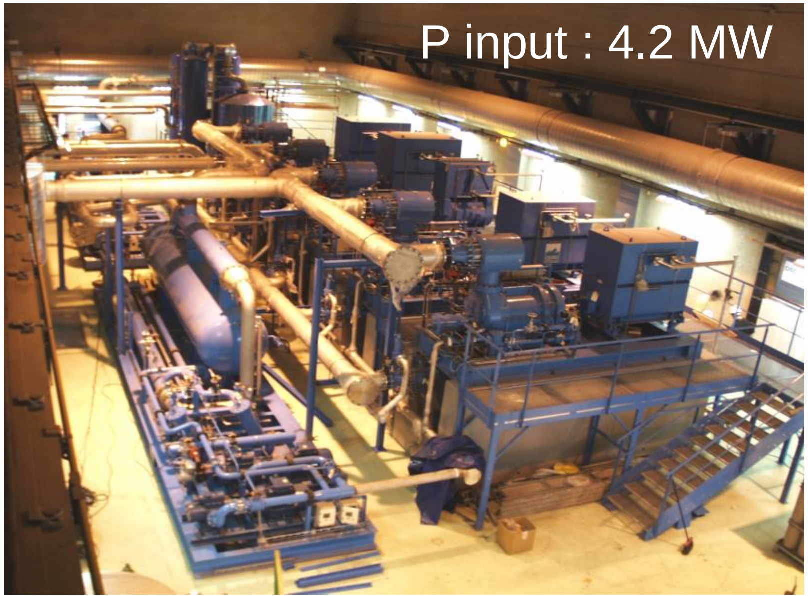
800 g/s @ 1.05 bar

Oil removal system

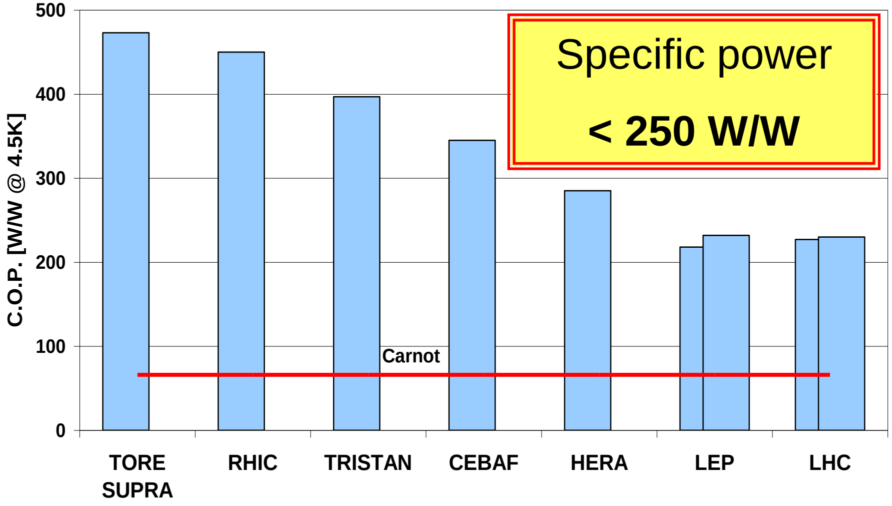
Examples of machines: « large » refrigeration Helium CERN

18 kW @ 4.5 K refrigerators

33 kW @ 50 K to 75 K - 23 kW @ 4.6 K to 20 K - 41 g/s liquefaction



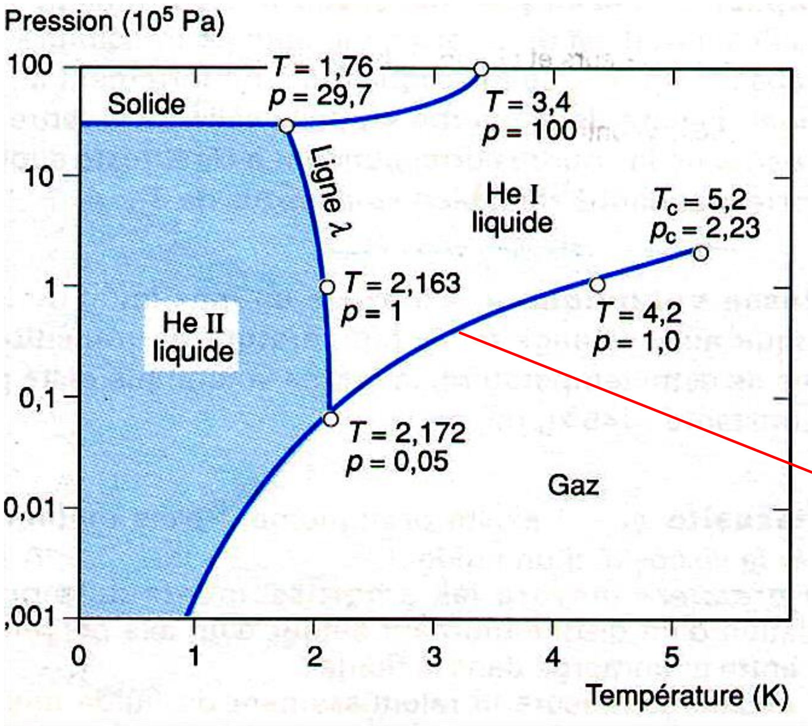
P input : 4.2 MW



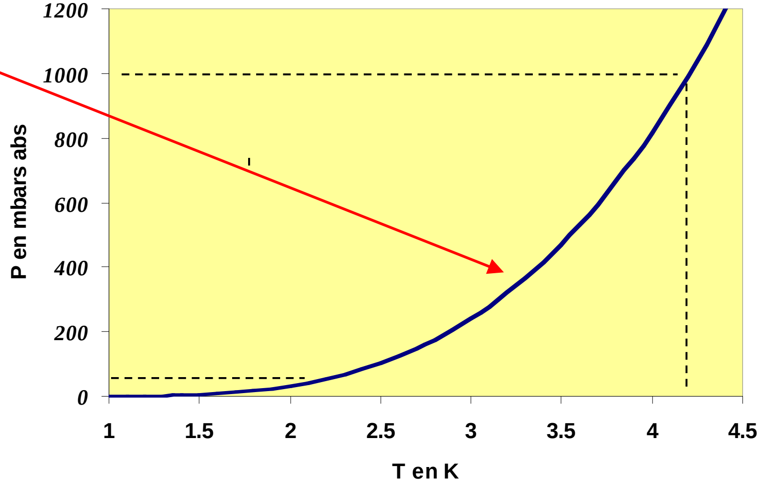
Specific power

< 250 W/W

Cycles for temperatures below 4,2 K (T_{sat} at 1 atm) (example : superfluid helium at T < 2,17 K)



Decreasing the temperature needs to decrease the pressure of a liquid helium bath [vapor saturation curve Tsat=f(Psat)]



=> Depressurising of circuits under atmospheric pressure !!!

=> Risk of air inlets, contamination =>plugging at low temperature…

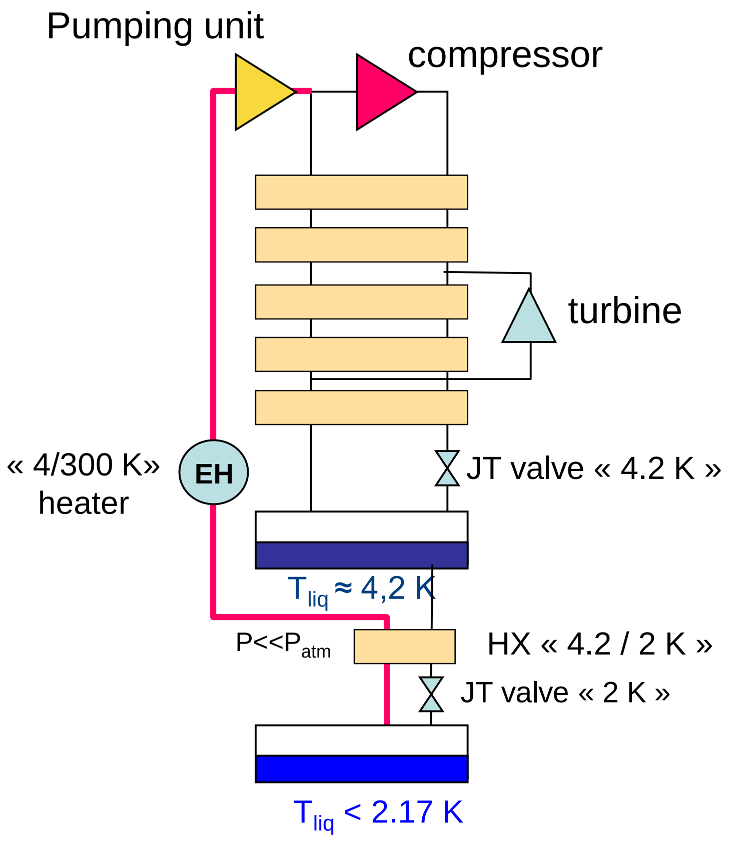
And additionnally, mass flow at low pressure leads to high pressure drop

=> Very large heat exchanger if used at very low pressure

Various possibilities to obtain T below 4.2 K ($T < 2.17$ K=> He II)

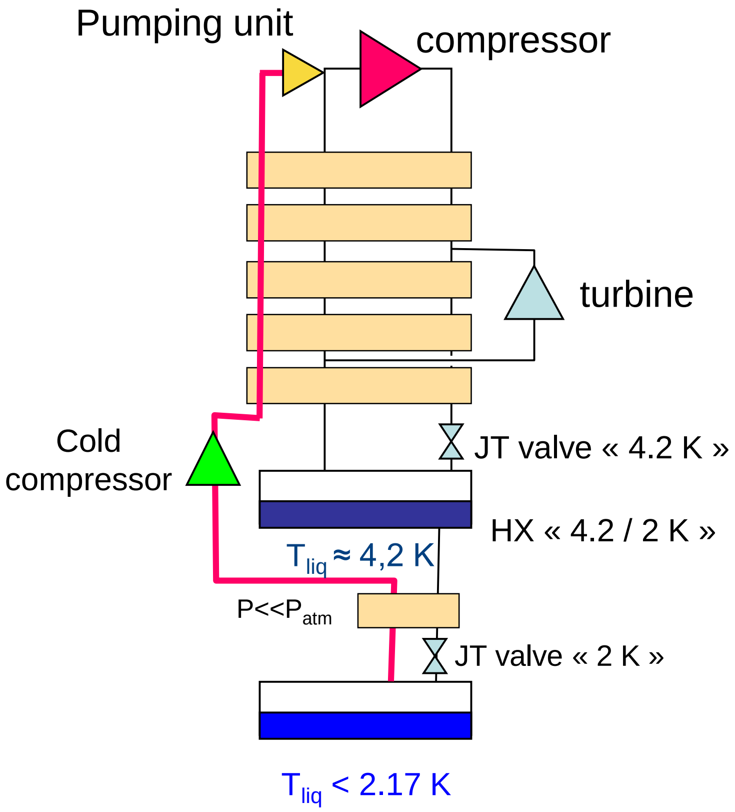
- **Pumping at room temperature**

small cold power at $T < 2.17$ K (< 4.5 g/s i.e < 100 W)



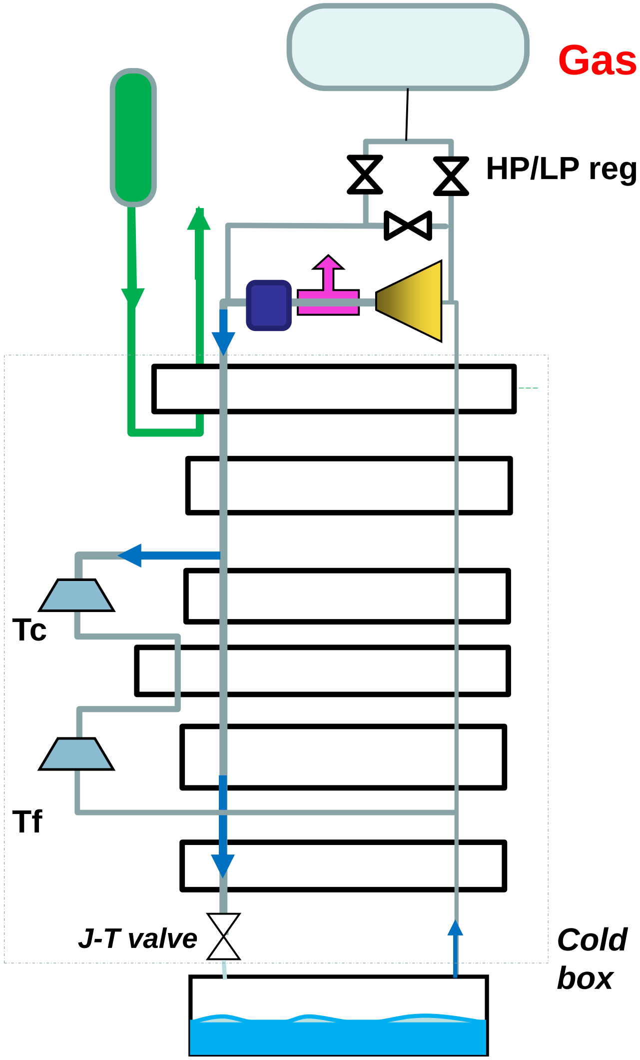
- **Cold compressors**

large cold power at $T < 2.17$ K (> 4.5 g/s i.e > 100 W) and continuous operation



Typical components for helium refrigeration machines (recuperative cycle)

Gas buffers for pure He storage



« ***Lungs* » *of the cryoplant* :**

Volume to give or recover pure gas for cycle

2 x 100 m3 for a 150 l/h liquefier :

- Redundancy for maintenance (PED)

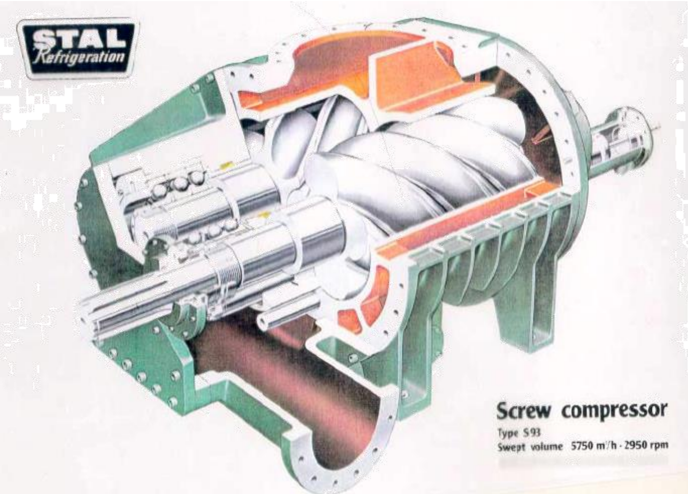
He compressor

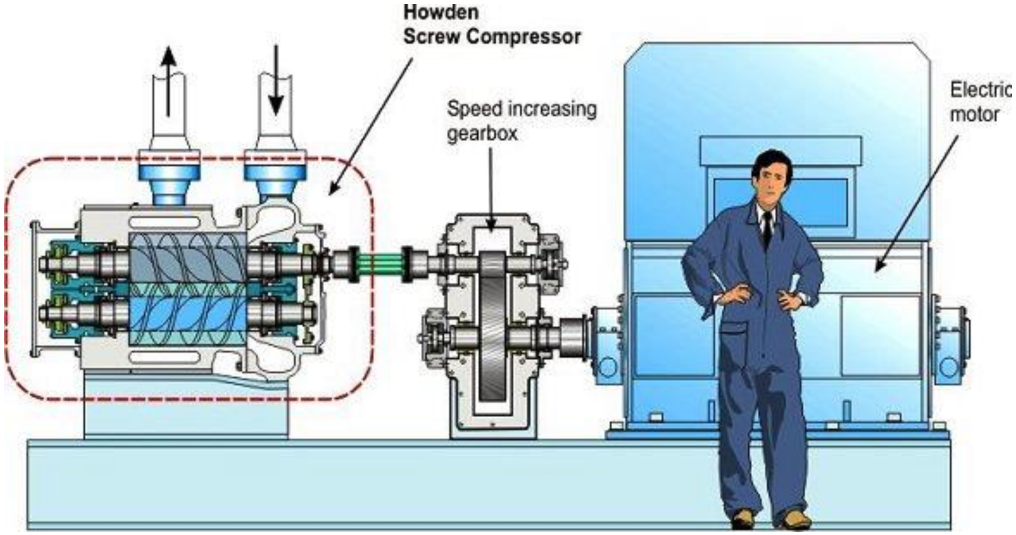
Classically, **screw compressors** for helium cycles

Generally

- multi-staged (2), up to 21 bars, with devices in // above 5000 Nm^3/h
- Lubricated screws

=> extraction of heat compression thanks to oil as extra media
=> lubrification !



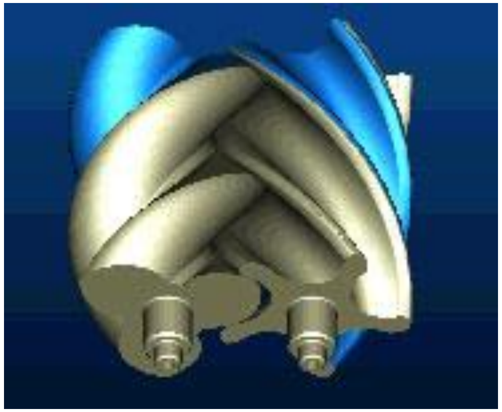


R : High efficiency centrifugal compressors have technical difficulties with He (compression rate and overheating due to helium properties)

screw compression

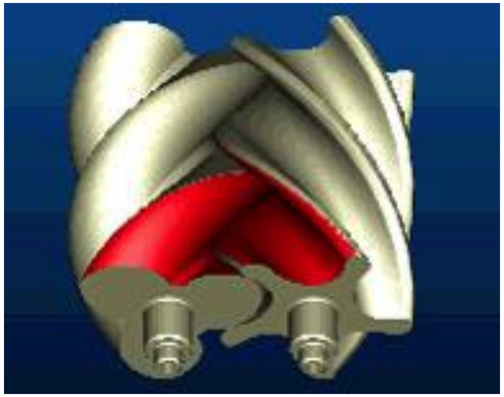
n-1 lobes
Male screw

n grooves
Female screw



Suction phase: The gas enters through the suction port into the rotor turns opened on the suction side

Compression phase: the progressive rotation of the rotors causes the gas inlet orifice to close, the volume is reduced and the pressure rises.



Evacuation phase: compression is complete, final pressure is reached and discharge begins..

Examples of He screw compressor

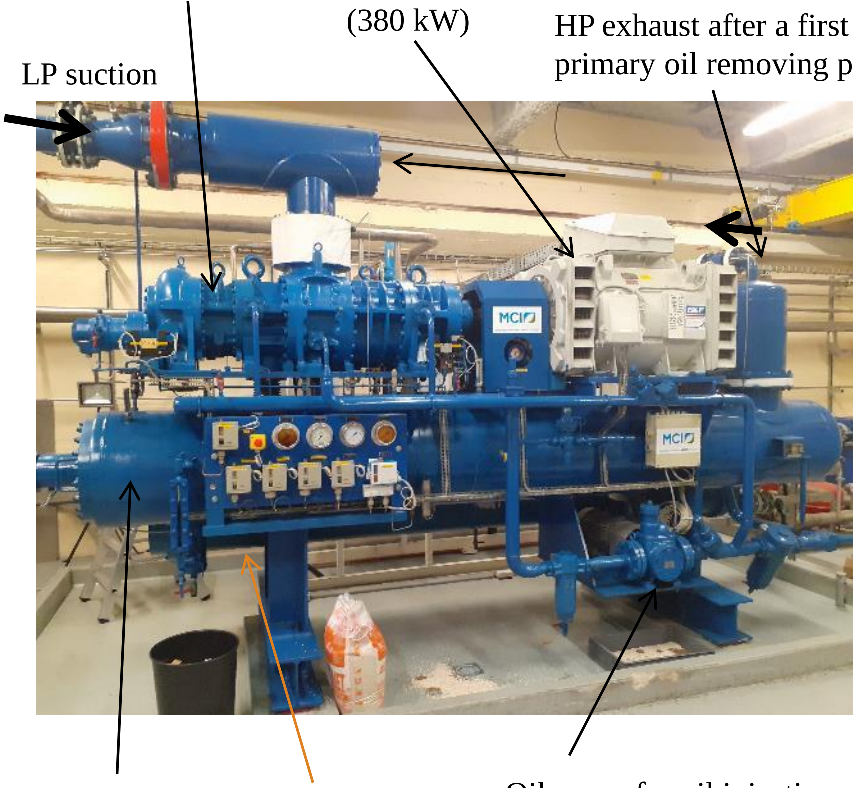
Standard compressor

< 100 g/s & 300 kW

He screw compressor KAESER

(15 bars - 80 g/s)

Specific compressor skid



Screw compressor (2 stages)

Electrical motor (380 kW)

HP exhaust after a first primary oil removing pot

LP suction

HP tank for oil decanting

Exchanger cooling water/oil

Oil pump for oil injection inside the screws

He screw compressor MYCOM

(16 bars - 90 g/s)

Compressors, oil and ORS (oil removal skid)

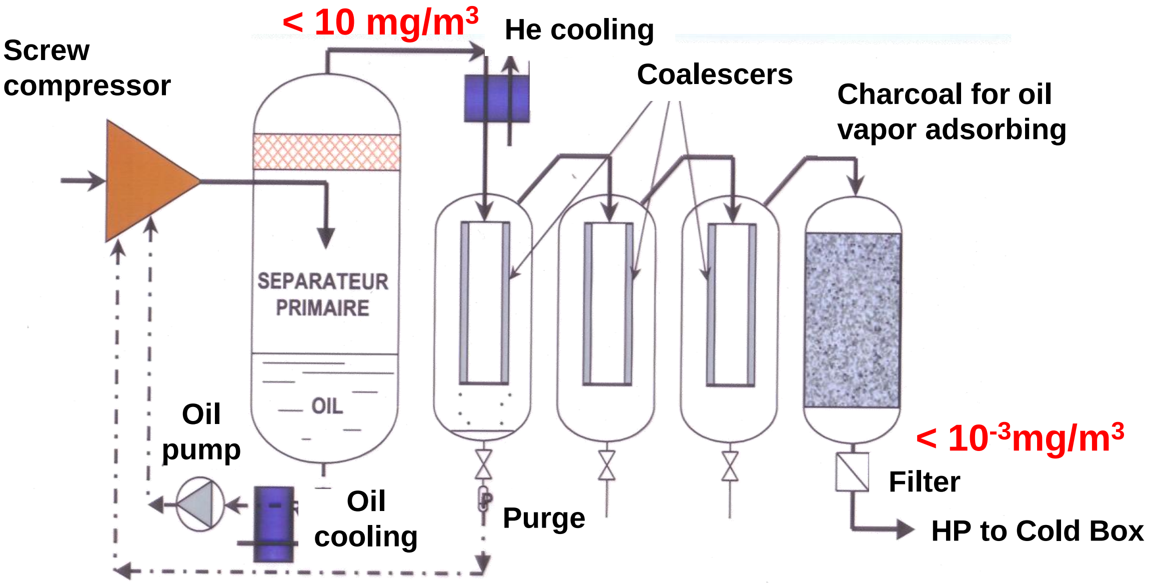
Need of oil for cooling the compression

R : Adiabiatic compression from 1,05 to 15 bars (Tinit=300 K) $\frac{T_{hp}}{T_{bp}} = \left(\frac{P_{hp}}{P_{bp}}\right)^{\frac{g-1}{g}} \Rightarrow T_{hp} \approx 870\,K \quad (597°C!!!)$

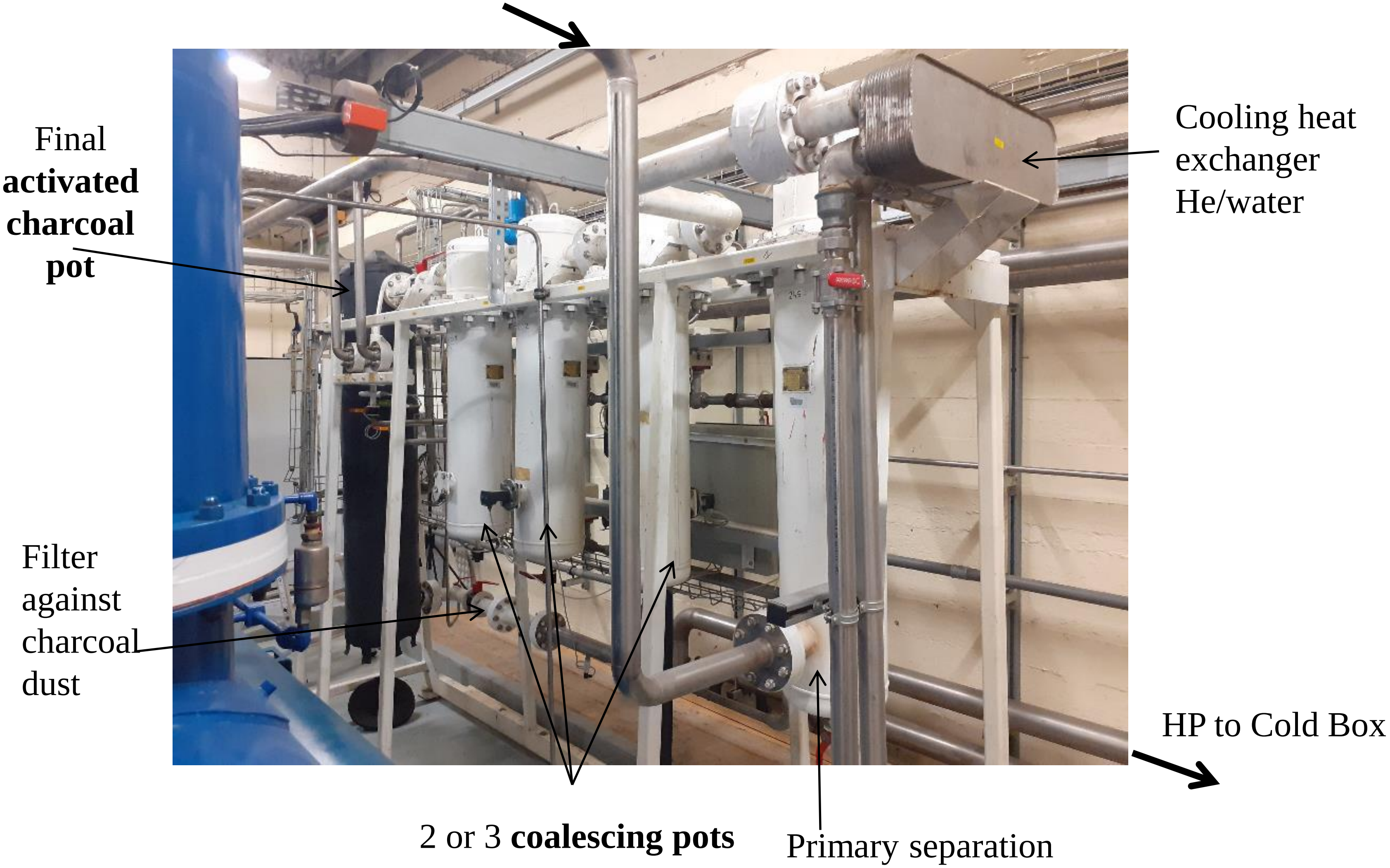
Injection of oil with helium will absorb a large quantity of compression heat (pulverisated oil in order to have a large exchange surface).

Typically, **1 g/s of compressed He** needs to be mixed with **35 g/s** of oil for an efficient cooling

An Oil removal system is mandatory for supplying the cold box with pure HP gas



ORS (oil removal skid)



HP from compressor

Final **activated charcoal pot**

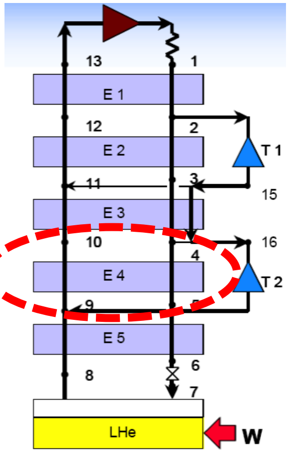
Cooling heat exchanger He/water

Filter against charcoal dust

HP to Cold Box

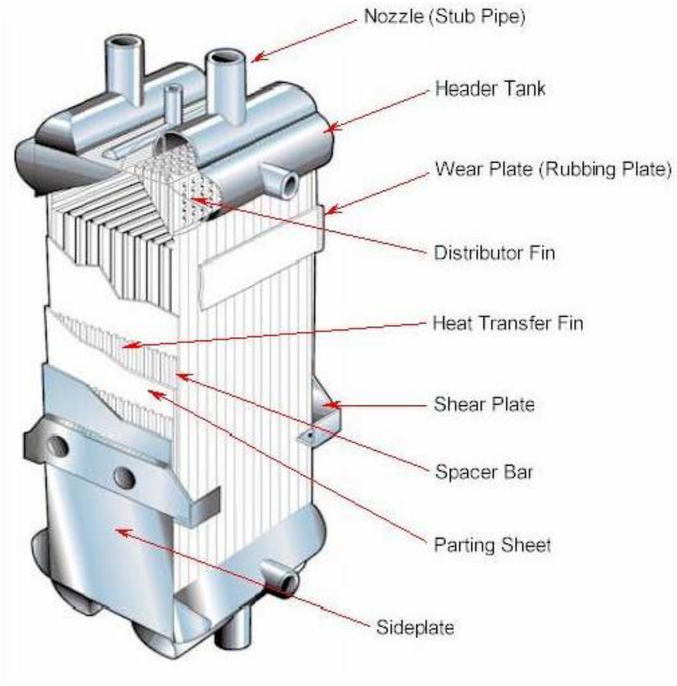
2 or 3 **coalescing pots**

Primary separation



Cold box internal components

HX battery made of several plate heat exchanger (Al brazed)

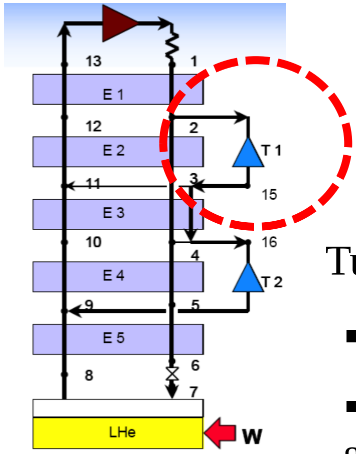


High compacity : 850 à 1500 m^2/m^3

« 25 kW @4.5 K » ITER cold box

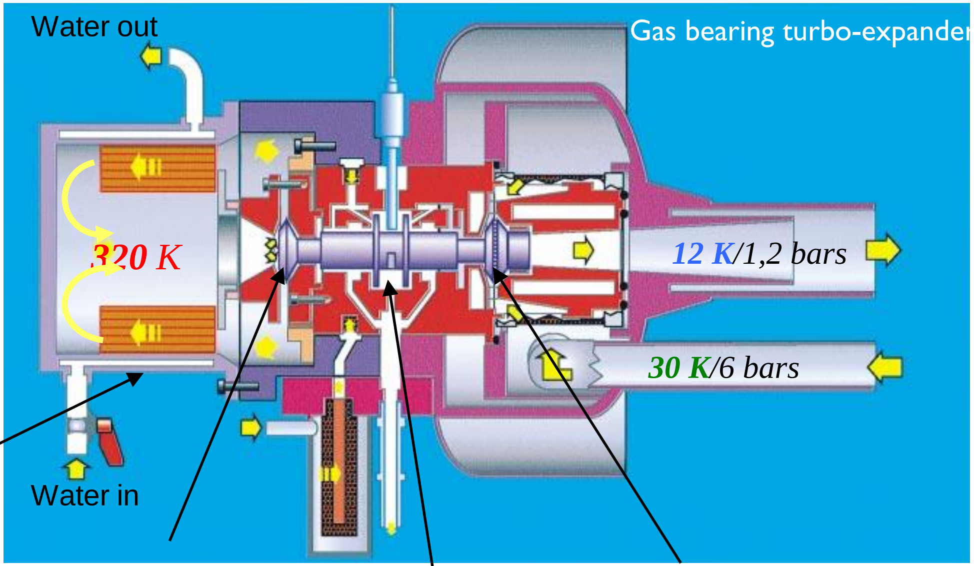
Cold box internal components

Turbo-expanders : « turbine » for quasi-isentropic expansion



Turbo-expanders :

- **high rotation speed** (up to 4000 tr/s)
- **gas bearings** with very small fonctionnal gaps (a few µm) for a high efficiency($\eta \approx 0{,}7$)
- large difference of temperature between expansion wheel and brake wheel (> 250 K)
- expansion rate : 6 à 10
- MTBF > 100 000 h



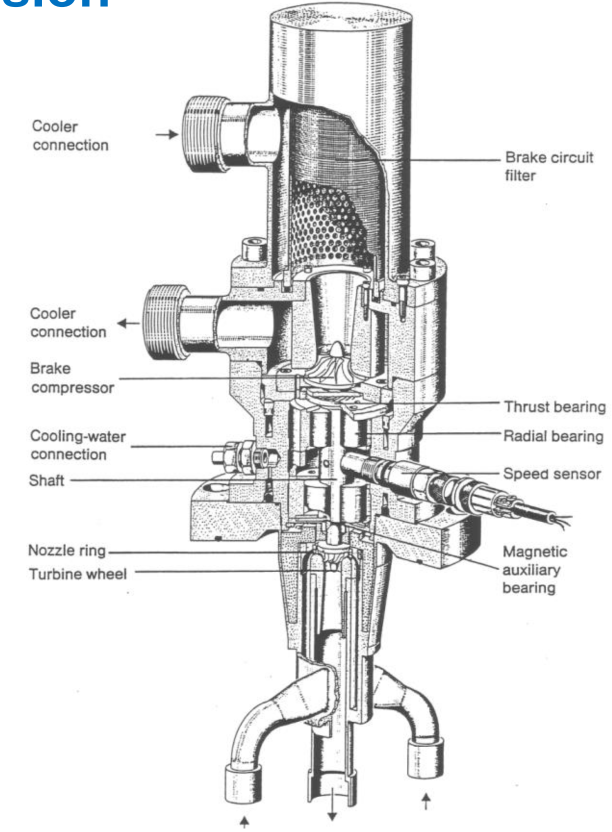
H_20/He heat exchanger (>Tamb)

Brake wheel

Gas bearings (Tamb)

Expansion turbine wheel (Tcryo)

Courtesy : Air liquide



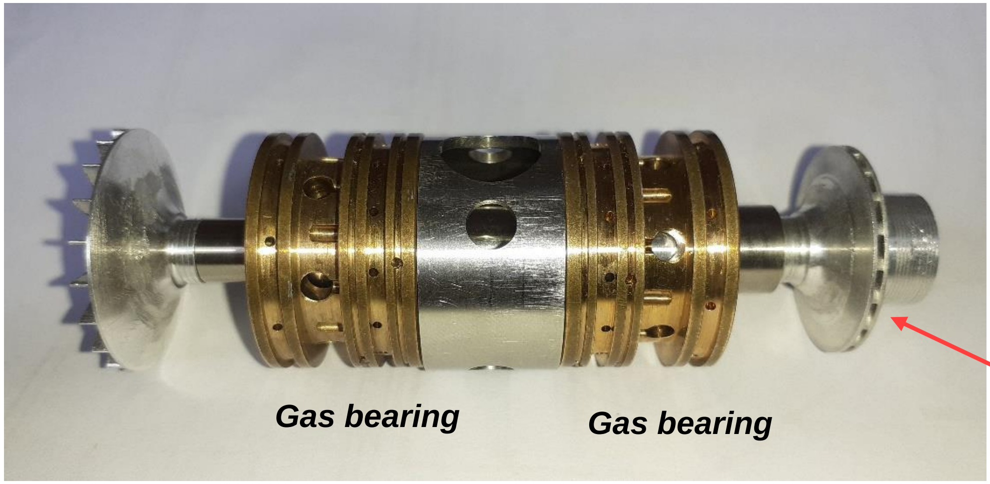
Exploded view of He refrigerator turbo expander(origin SULZER/LINDE)

Turbine wheel

Cold box internal components

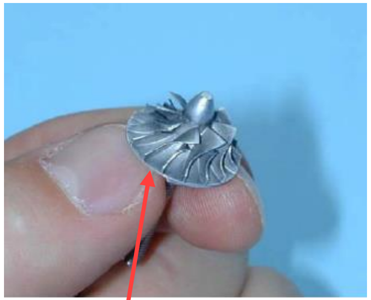
Example of turbo-expander

Brake wheel



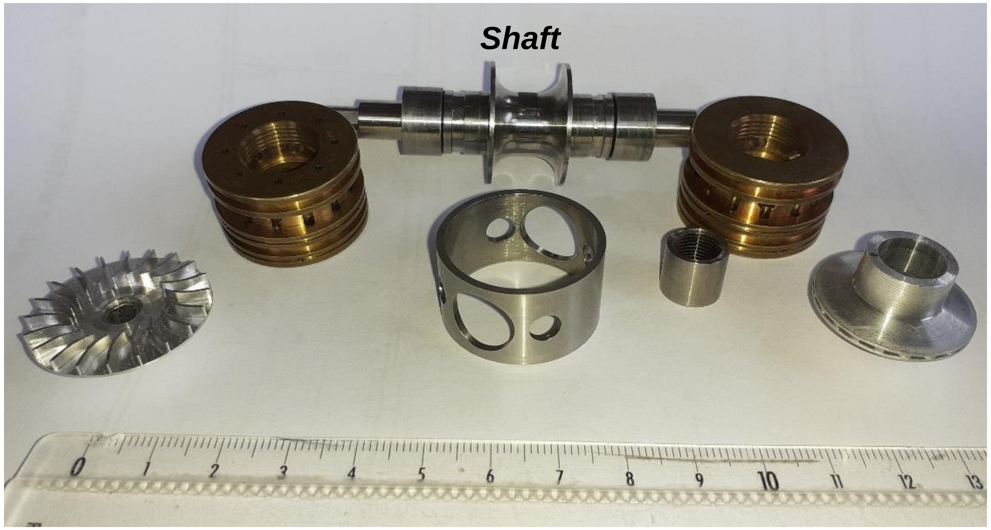
Gas bearing

Gas bearing



***Turbine wheel**:*
- *Open type*
- *closed type*

Shaft



Complementary equipment for cycles at T < 4,2 K : cold compressors

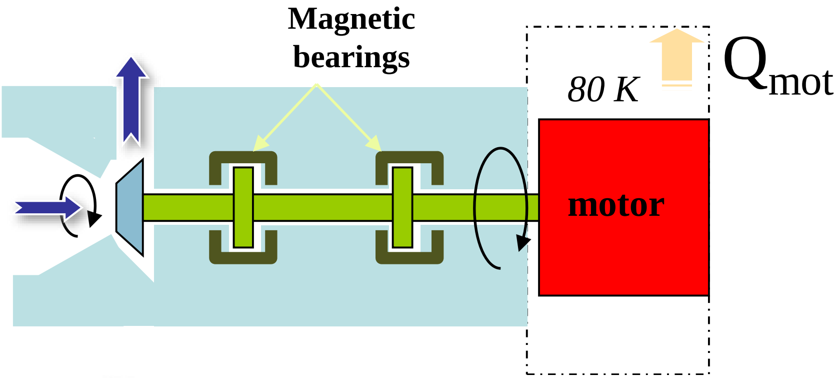
They allow compression of cold gas below Patm. Same general conception than a turboexpander but with classically magnetic bearings and a ratio of compression in He around a factor 3. To reduce heat leaks, motor can operate at LN_2 temperatures..

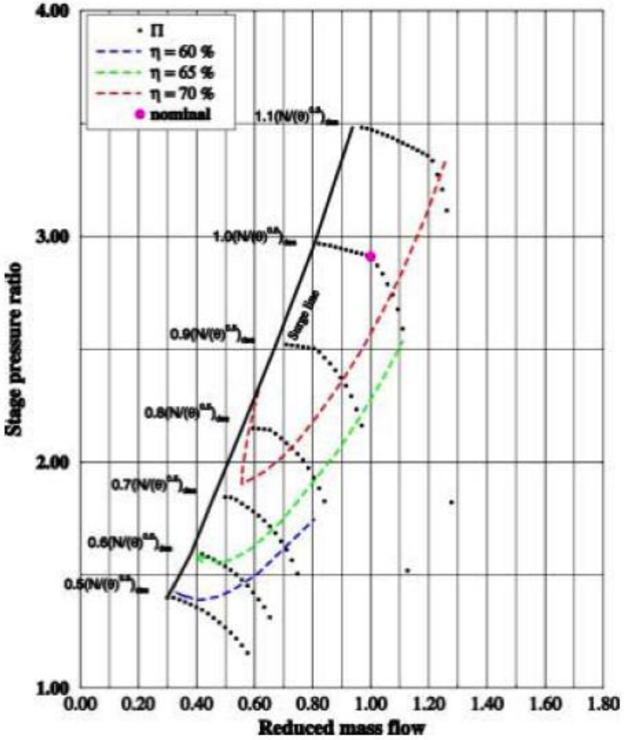
Compression field limited (see example on curve)

$\eta \approx 0,7$

Compression ratio ≈ 3

Installation in serial is possible taking care about speed regulation of each compressor.



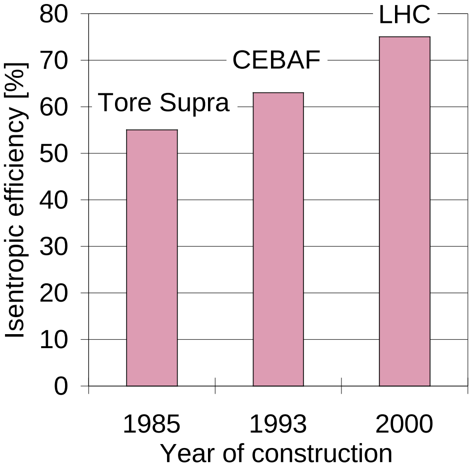


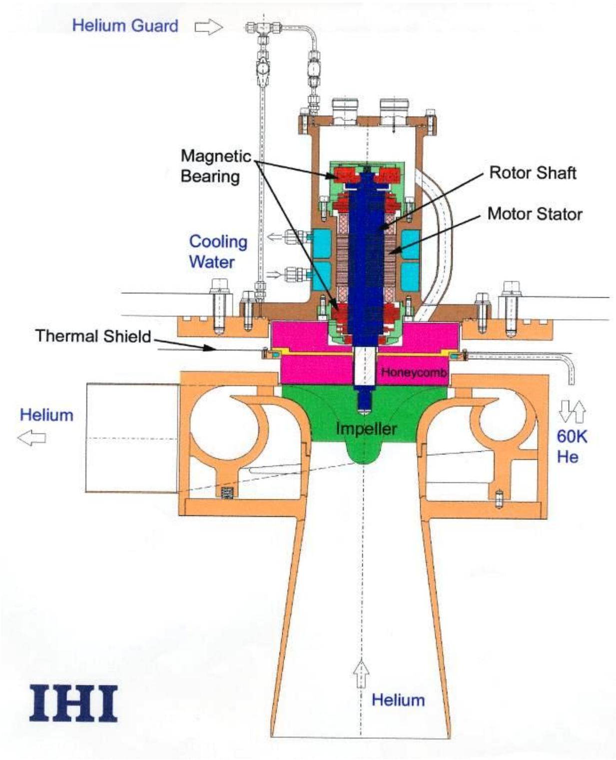
Complementary equipement for cycles at T < 4,2 K : cold compressors

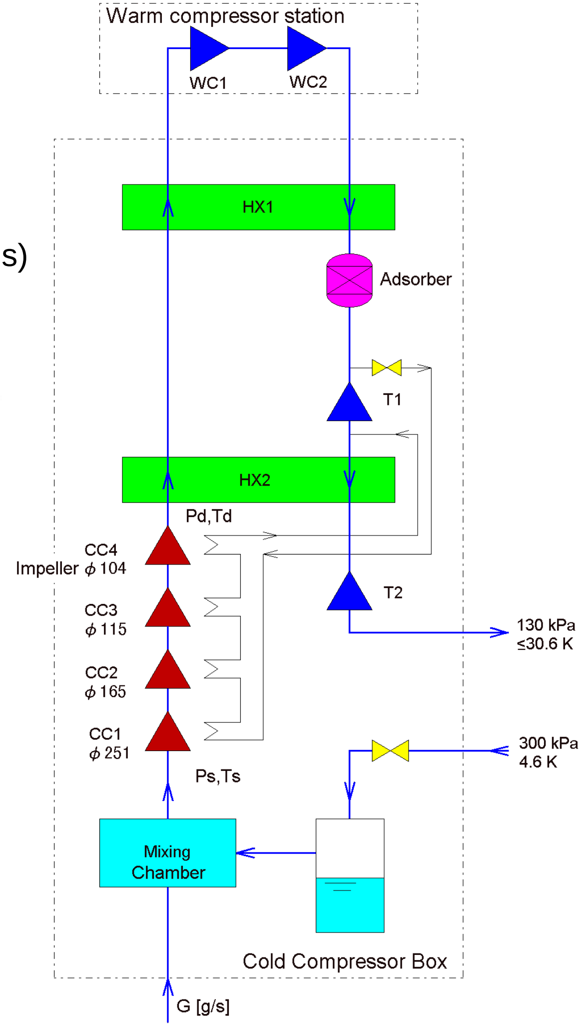
- High isentropic effiiency
- High reliability
- Easy handling and maintenance

Technical challenges:

- 3D wheel and low heat leaks
- no lubrificant (magnetic bearings)
- “Cartridge” design





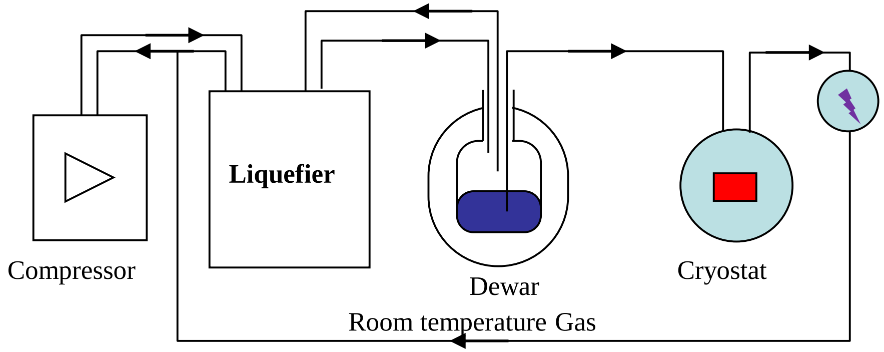


Mode	Installed	Normal	Low intensity
Ps kPa	1.40	1.46	1.47
Ts K	3.96	3.95	4.20
Pd kPa	62.2	42.2	33.2
Td K	27.35	21.83	20.77
G g/s	125.7	84.69	63.89

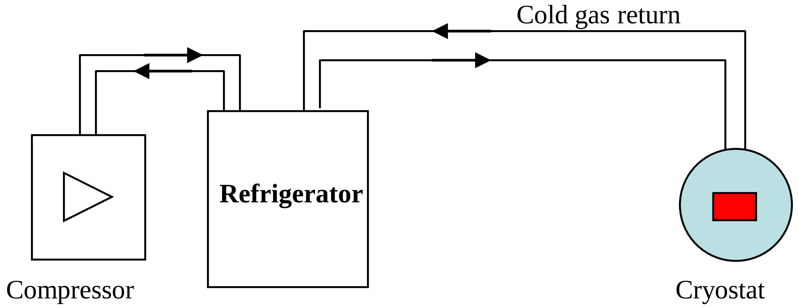
LHC :Refrigeration unit 1.8K

Refrigerator or liquefier

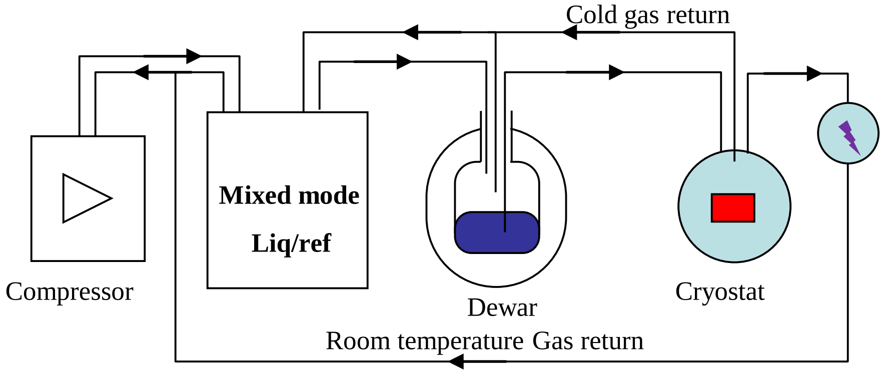
Liquefier mode
Capacity in l/h (or g/s)
Independance of equipment
Low efficiency
Large turbo-expanders



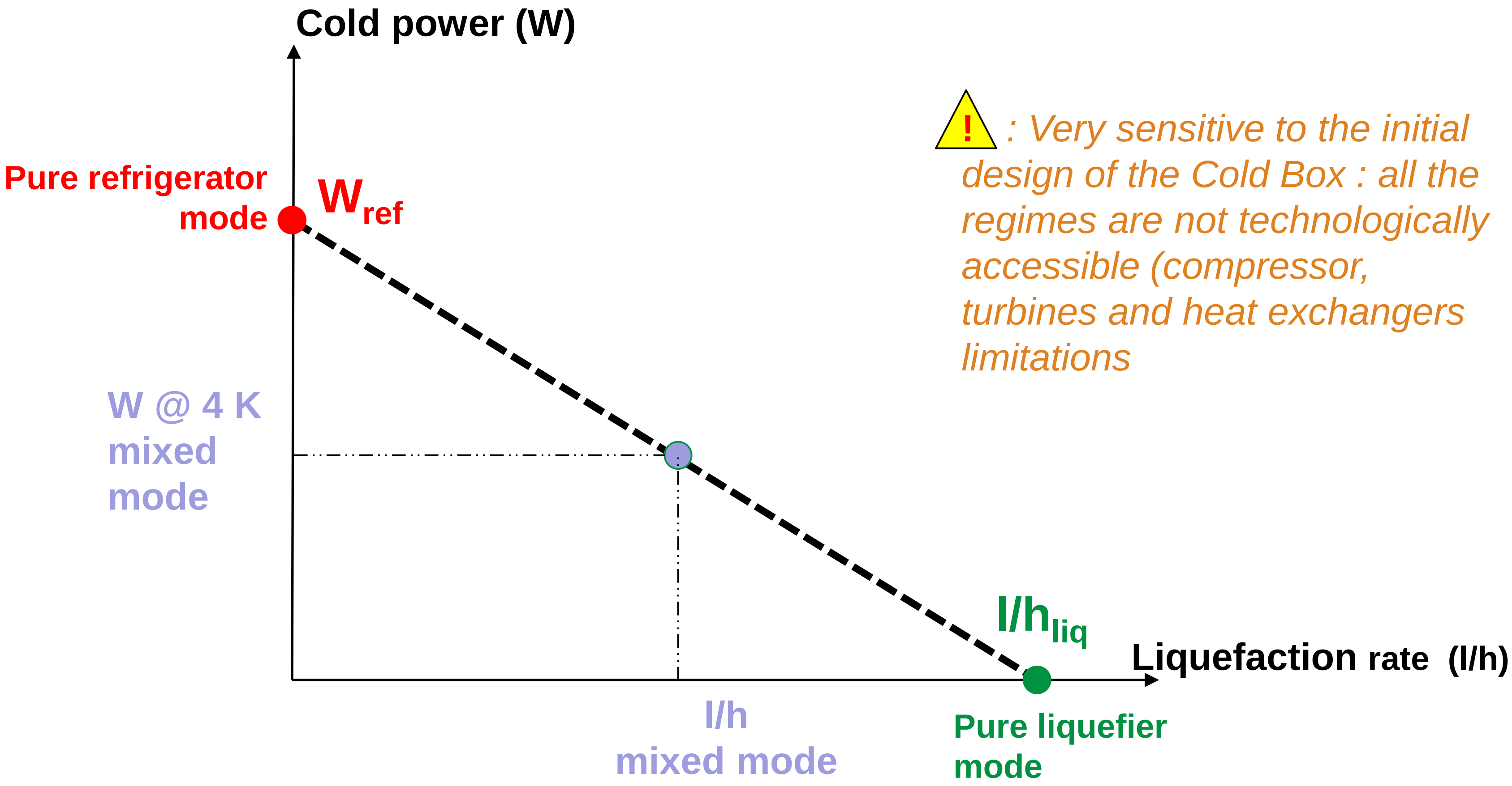
Refrigerator mode
Capacity in « W at 4 K »
Better efficiency
Equipment strongly interacting
Large heat exchanger



Mixed mode
W at 4 K + l/h (or g/s)
Adaptative



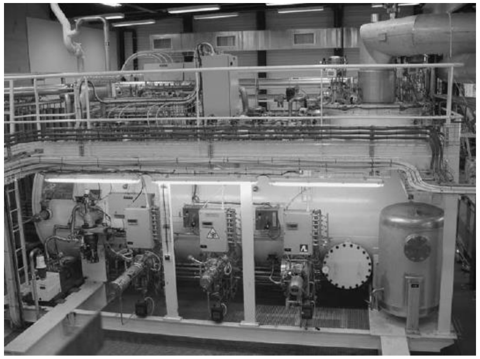
Approximative estimation in mixed mode

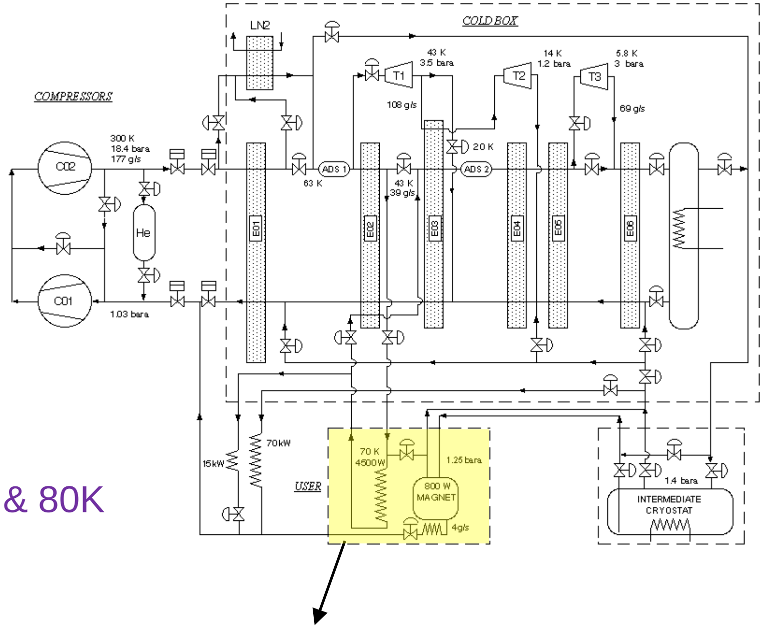


⚠ *: Very sensitive to the initial design of the Cold Box : all the regimes are not technologically accessible (compressor, turbines and heat exchangers limitations*

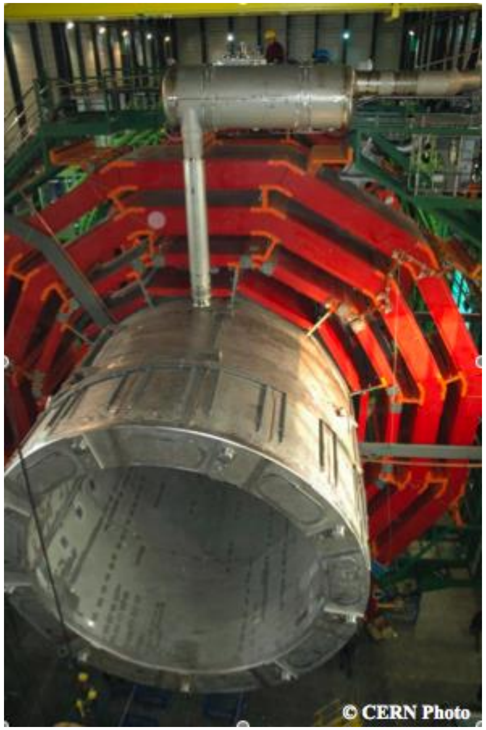
Example: CMS refrigerator (mixed mode) and its magnet

CMS cold box





- 225 tons at 4.5 K to be cooled in 3 weeks
- Refrigeration part 170/400 W at 4.5 K
- Liquefaction part 2.5 g/s
- Thermal shielding 3000 W between 60 & 80K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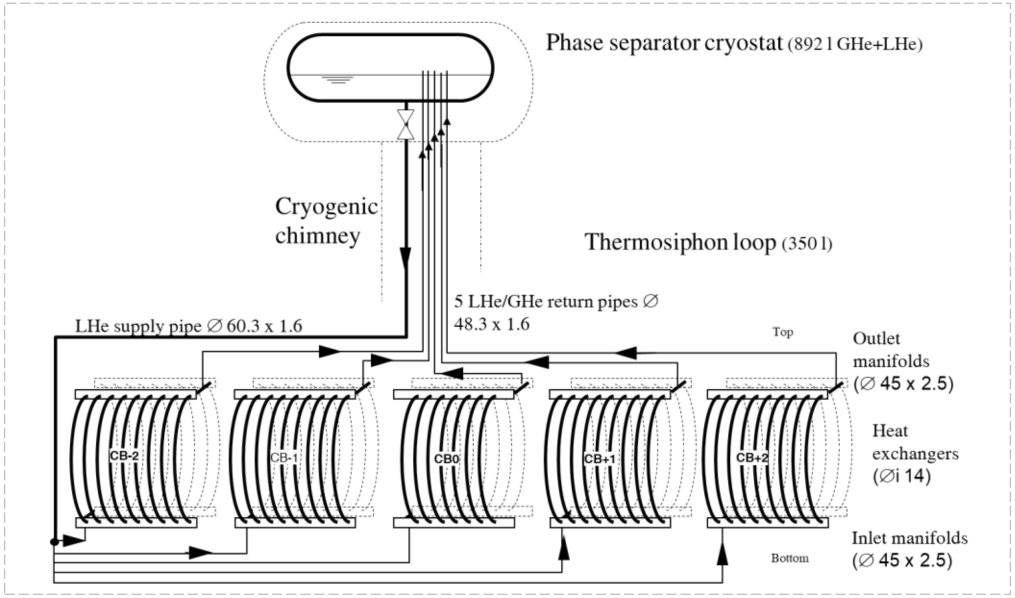


Example: CMS refrigerator (mixed mode) and its magnet

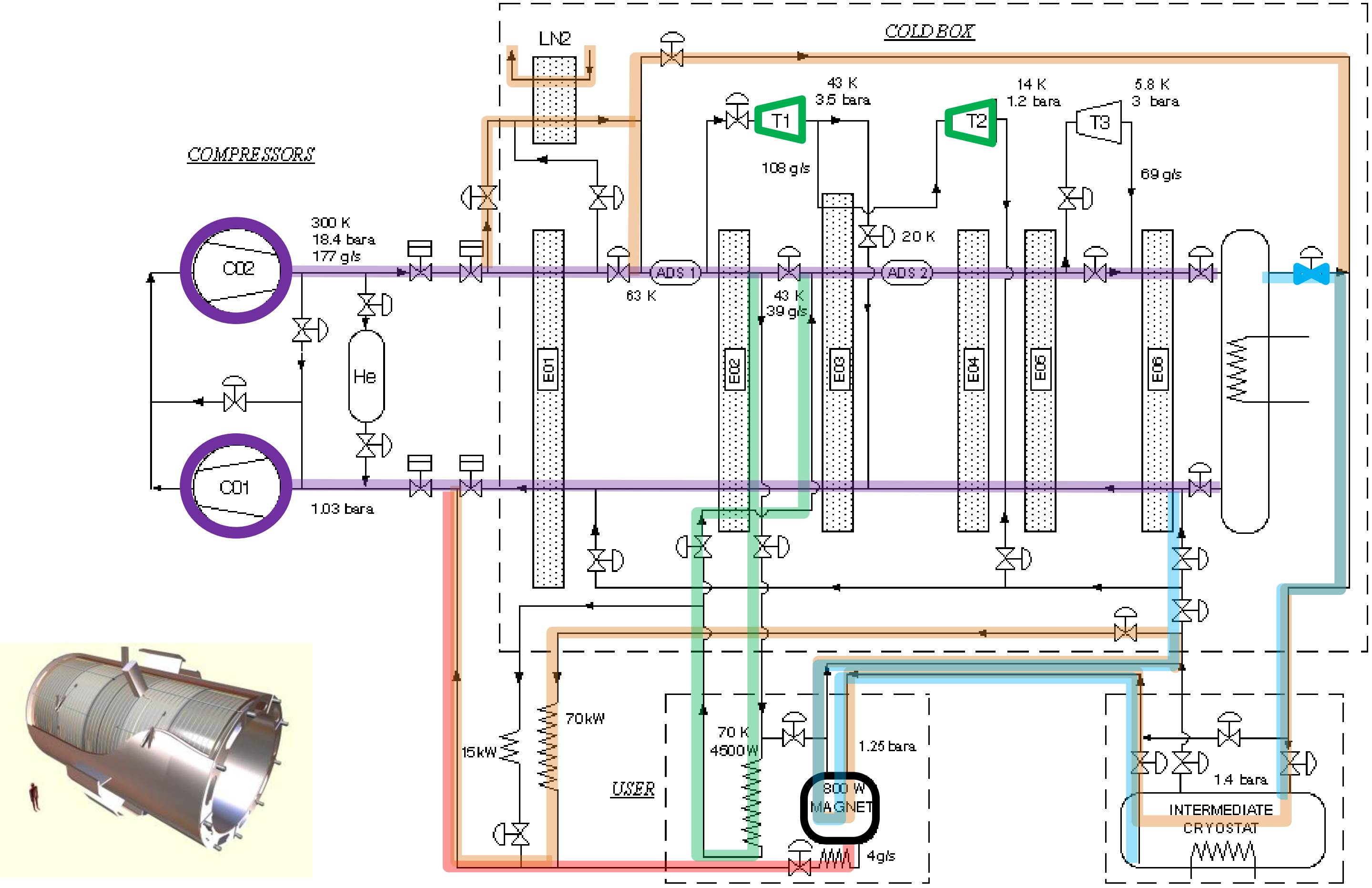
150 g/s between 300 K and 80 K for magnet pre-cooling (225 t)

then simultaneously

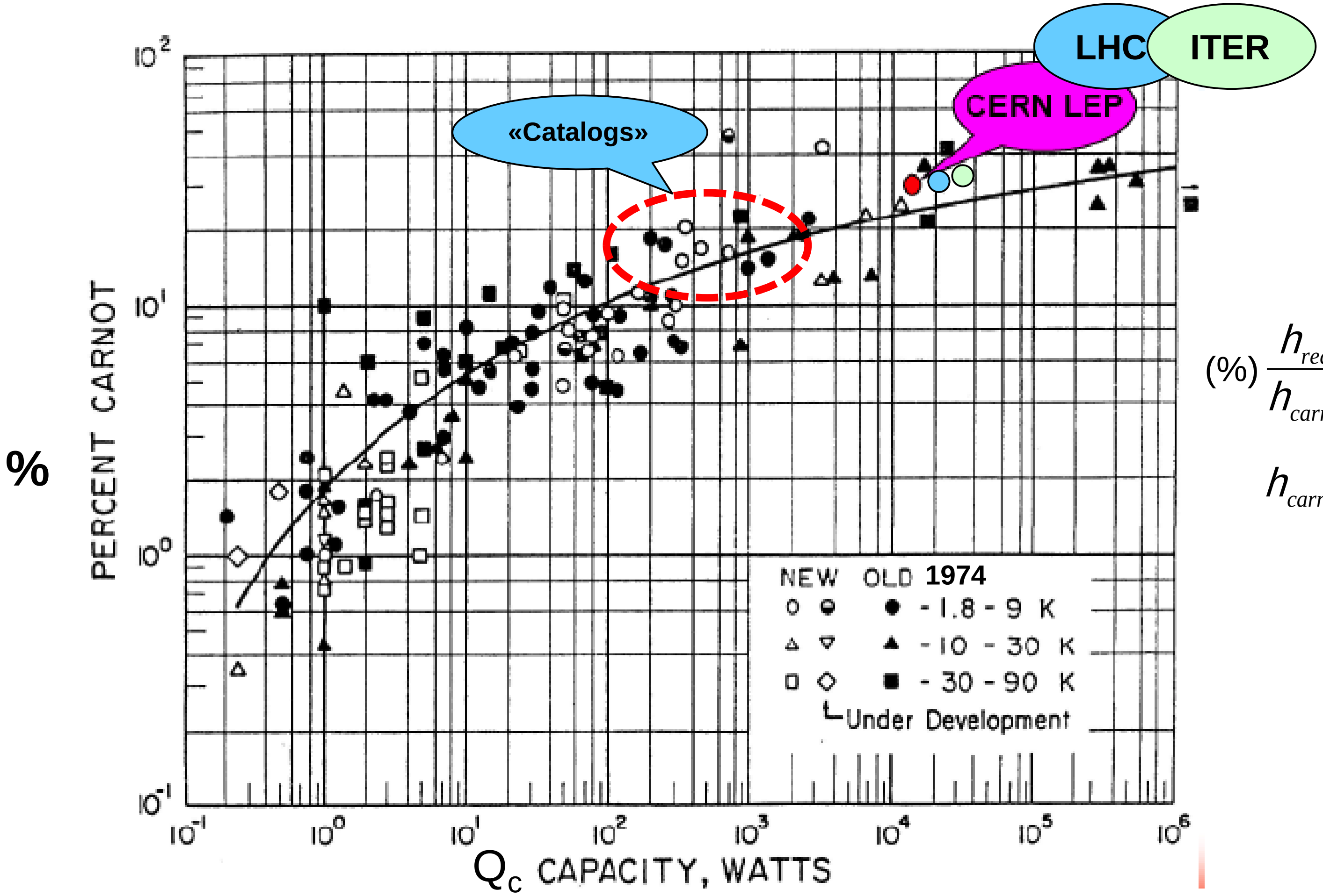
4500 W (max) between 60 K & 80 K for magnet thermal shielding

800 W (max) at 4.45 K for Sc magnet cooling

4 g/s liquefaction for current leads (2 x 20 kA)



Strobridge Diagram



$$(\%)\ \frac{h_{real}}{h_{carnot}} = f(Q_c)$$

$$h_{carnot} = \frac{T_c}{T_h - T_c}$$

High power users are well served !
Large capacity machines have the best efficiency .

ex: Ideal Carnot at 4 K = 70 W_{cold}/W_{cons} but really

- *- **LHC** : 240 W_{cold}/W_{cons} => < 30 % Carnot*
- *- **Commercial** : 500 to 750 W_{cold}/W_{cons} = > < 15 % Carnot*
- *- 4 K G-M **cryocooler** : 1.8W_{cold} /7200W_{elec} => < 2% Carnot*

Summary

For large cooling power, possibly down to 1.8 K, recuperative machines based on the Claude cycle are used, integrating :

Oil lubricated screw compressor
Oil removal system
Several turboexpanders
Battery of counterflow exchangers
JT valve
Possibly 2 K stage with pumping units and/or cold compressors

- Commercial standard helium :
  - liquefiers available from 15 l/h to 600 l/h
  - refrigerators available from 100 W to 1000 W @ 4.5K
- Customized plants for helium liquefiers larger than 650 l/h and refrigerators larger than 1000 W @ 4.5K (ex : up to 25 kW (ITER) or 8000 l/h (Qatar plant))
- Experiments below 2.2 K can use cold compressor technology above 100 W of power.

Only a few european manufacturers (above a few tenths l/h) :

- *Air Liquid Advanced Technology*
- *Linde Kryotechnik AG*
- *Vorbuchner GmbH & Co(< 50 l/h)*

R :For small cooling capacities (a few W at 4 K or a very few l/h of LHe), another concept exists to avoid LHe purchase: using a ***cryocooler****. This is another story…*

Thank you for your attention.